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التاريـــخ: / /

نموذج رقم (18)
اقرار والتزام بالمعايير الأخلاقية والأمانة العلمية
وقوانين الجامعة الأردنية وأنظمتها وتعليماتها
لطلبة الماجستير

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عنوان الرسالة: **Evaluation of Solid Waste Management in Zarqa City**

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اعلن بأنني قد التزمت بقوانين الجامعة الأردنية وأنظمتها وتعليماتها وقراراتها السارية المفعول المتعلقة باعداد رسائل الماجستير عندما قمت شخصيا" باعداد رسالتي وذلك بما ينسجم مع الأمانة العلمية وكافة المعايير الأخلاقية المتعارف عليها في كتابة الرسائل العلمية. كما أنني أعلن بأن رسالتي هذه غير منقولة أو مستلة من رسائل أو كتب أو أبحاث أو أي منشورات علمية تم نشرها أو تخزينها في أي وسيلة اعلامية، وتأسيسا" على ما تقدم فانني أتحمل المسؤولية بأنواعها كافة فيما لو تبين غير ذلك بما فيه حق مجلس العمداء في الجامعة الأردنية بالغاء قرار منحي الدرجة العلمية التي حصلت عليها وسحب شهادة التخرج مني بعد صدورها دون أن يكون لي أي حق في التظلم أو الاعتراض أو الطعن بأي صورة كانت في القرار الصادر عن مجلس العمداء بهذا الصدد.

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EVALUATION OF SOLID WASTE MANAGEMENT IN ZARQA CITY

By

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Supervisor

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This Thesis was Submitted in Partial Fulfillment of the Requirements for the Master's Degree of Science in Civil and Environmental Engineering

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COMMITTEE DECISION

This Thesis/Dissertation (Evaluation of Solid Waste in Zarqa City) was successfully Defended and Approved on August/2011

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DEDICATION

I dedicate this thesis to my Parents, my Father and Mother in law, my soul mate my Wife, my Daughter and my Brothers and Sisters. Without their patience, support, understanding and most of all unconditional love, the completion of this work would not have been possible.

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LIST OF ABBREVIATIONS

CCS: Common Council Services

CEA: Country Environmental Analysis

CEI: Community Effect Index

CMCE: Cabinet Merlin Consulting Engineers

DOS: Department of Statistics

GAM: Greater Amman Municipality

GDR: Gross Domestic Product

HHV: Highest Heat Value

ISWM: Integrated Solid Waste Management

MoEnv: Ministry of Environment

MRF: Material Recovery Facility

MSW: Municipal Solid Waste

RDF: Refuse Derived Fuel

RPM: Round Per Minute

RSS: Royal Scientific Society

SW: Solid Waste

US DOE: United State Department of Energy

USI: User Satisfaction Index

WTE: Waste to Energy

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EVALUATION OF SOLID WASTE MANAGEMENT IN ZARQA CITY

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ABSTRACT

There is great interest in solving problems related to solid waste management in Jordan. During the last few years, different studies have been conducted to evaluate the solid waste management process in Jordan. Zarqa city became a hot environmental spot and the solid waste management in Zarqa city became an obvious challenge especially after closing Al-Rusaifeh landfill in 2003. This study aims to assess the current solid waste management activities in Zarqa city; the study analyzes several solid waste elements such as collection, transportation and the problems faced by the municipality during handling of the solid waste. Moreover, solid waste generation rate, composition, heat content and other service performance indicators were determined. Several questioners were distributed and the user satisfaction index (USI) was calculated.

The total solid waste generated in Zarqa is around 299 tons/day with generation rate about 0.69 kg per capita per day. Organic fraction of solid waste was 48.9% which requires special considerations for waste handling and disposal. The other solid waste components were 13.3% 15.2%, 3.1% and 5.8% for paper and cardboard, plastic, metals, and textile, respectively. The density of the solid waste was measured to be around 165 kg/m^3. The heat content was between 2,121 – 2,905 kcal/kg.

The USI for solid waste collection service was calculated to be around 68% for domestics and 68.8% for commercial sectors. Moreover, community effect index (CEI) was used to evaluate the cleanness of the city, and it was found to be around 53.

Some deficiencies were found in solid waste management elements, for example the collection element deficits in term of manpower and vehicles availability, absence of bins in the city center increases the littering problem, the bins installation and operation costs in the city center and bus stations were found to be around 40,463 JD per year, damaged solid waste containers and the piles of waste near the container need more time to be collected, and cost the municipality extra money, the extra cost may reach 90,000JD annually. Lack of trained staff and people awareness, damaged solid waste containers, and route planning are responsible for poor solid waste handling in the city.

1 INTRODUCTION

The quality of environment is an important determinant of human health. The deteriorating of environmental conditions are major contributory factors to poor health and poor quality life, which hinders sustainable development. Most of developed countries suffer from serious solid waste (SW) management problems due to rapid population growth (Suttiback and Nitivattananon, 2008).

Municipal solid waste (MSW) generation increases rapidly and untidy in Jordan due to population growth rate and unexpected migration to Jordan. Furthermore, the urbanization and the new life style play a main role in increasing solid waste generation rate (Al-Ansari, et al., 2005).

The improper solid waste management may lead to health, fire hazards, public nuisance, air, water and soil pollution problems, in addition to visual pollution and degradation of landscape. Solid waste management process is costly and time consuming, requiring complex measures to be controlled, for example, storage collection, transportation and disposal in accordance with the principles of public health and economic (METAP, 2005).

In Jordan, the solid waste handling is the responsibility of municipalities. In which, the municipalities collect the SW then transport it to a transfer station or landfill for disposal. The landfills management and operations are done by independent community called Common Council Services (CCS).

According to the Ministry of Environment (MoEnv) the average SW generation rate in Jordan is 0.9 kg per capita per day, and the total solid waste generation rate is around 5,500

tons per day, where the percentage of SW collection from urban areas reaches 95% and 90% in rural areas (MoEnv, 2010).

Currently, there are 23 landfills in Jordan; most of these landfills are operated by the CCS except Al-Gabawi landfill which is operated by the Greater Amman Municipality (GAM) and some other rural landfills which are operated directly by their municipality. The reason that these landfills are not operated by the CCS is that either landfills are located in isolated areas or they receive small amount of solid waste.

The current legislations, which include the environmental protection law No. 52 for the year 2006 municipal and public health laws, tackle the SW issue in a generic way. The current laws do not address the solid waste issue in a comprehensive manner. Realizing that, MoEnv has finalized recently a draft waste law which is supposed to be considered as the base to develop and improve the solid waste management (Sweep net, 2010).

Zarqa city is one of the largest cities in Jordan, according to the Department of Statistics (DOS), the population in Zarqa city is around 470,760 persons for the year of 2010. The city of Zarqa is considered one of the hottest environmental spots in Jordan due to the nature of activities within the city. The different activities in the city generate all type of solid waste, for instance, industrial, agricultural, commercial, institutional and residential. Moreover, the bus stations in the city, which deals with hundred thousands of passengers daily, generate extra amount of solid waste. Zarqa municipality is responsible for all kind of solid waste handling and disposal activities.

The large amount of solid waste produced in Zarqa city on daily basis is a major environmental problem that needs to be managed effectively. The research presented in this study focuses on the management of the solid waste in Zarqa city and suggests actions to enhance the current solid waste management situation in the city.

Solid Waste Management in Zarqa city became an obvious challenge especially after closing Al-Rusaifeh landfill in 2003. These challenges are clearly presented in Abu Qdaise study (2007) where the calculated Community Effect Index (CEI) for Zarqa city was 47.

The research presented in this study is the first to evaluate the overall municipal solid waste management in Zarqa City after closing Al-Rusaifeh landfill and switching to Al-Gabawi landfill. It identifies the quantity and the quality of solid waste generated in the city.

The municipality of Zarqa was established in 1928, following that and for SW organizational purposes the municipality was divided into nine districts. Each district has one manager and a staff of supervisors and workers depending on the district size and solid waste generation rate within the districts. In the last decades, the development in the city accelerated causing population size, economical and industrial activities to be doubled many times and thus causing serious challenges in different aspects to local authorities to handle and manage it.

In general, the unplanned city expansions and urbanization is the major problem in the city. It hinders achievement of the sustainable developments goals and causes extra pressure on the available limited resources.

Currently the SW in Zarqa city is collected and transported to a transfer station which is located 12 km from the city center to the south, after that the SW is transferred to Al-Gabawi sanitary landfill which is located in Amman, 37 km from the transfer station. Al-Gabawi landfill is the only sanitary landfill in the Jordan with bio gas recovery system and leachate collection and treatment facility.

1.2 Objectives

All services have to be reviewed and assessed from time to time, to ensure that development and quality of the services are within the standards. The municipalities should adopt continuous assessment plan for their SW management activities to gain the citizen satisfaction.

The research presented in this study is considered as a first step in the assessment process for the city of Zarqa. It gives the basic data and information as well as recommendations for the SW management and practices in Zarqa city. It summarizes the actual data in a scientific manner which it could be used as a tool for decision makers. The specific objections for the study are:

- Collection of basis data which are whether distributed in several documents, even not available in a written way or not available at all until now.
- Analysis the current status of solid waste management in Zarqa
- Discus methods to improve the current solid waste management activities.

- Discus different recommendations to benefit from the generated waste instead of being landfilled according to the best available techniques and the best environmental practices.

This research is presented in 5 chapters, the following chapter include the literature review which contains basic information related to SW management, then the research methodology which briefs the research procedures which aims to obtain reliable data, after that the discussions of procedures and the obtained results. Finally, the conclusions and recommendations of this research are presented.

2 LITERATURE REVIEW

2.1 Introduction

Since the beginning of humanity, both humans and animals have been using earth resources to support their life. As a result of these activities, waste is being produced. In early times the generated solid waste was not a major problem, because of the availability of space, the nature of the waste, in which most of, was degradable, and the amount generated was small to cause any noise. Problems with waste disposal can be traced from the time when humans start living in tribes, villages and big cities and communities.

The waste accumulation and disposal became a noticed problem and seriously affected the life of people. The population increment causes increase in the goods consumption which in return reflected the generation of the solid waste directly. Furthermore, the new life style, where the individuals consume more, because of production and marketing systems, that creates new demands to consume new and more products. All of these factors play major role in increasing the generation rate per capita (Tchobanoglous, et al., 1993).

The term waste refer to useless, unwanted or discarded materials resulting from individuals or communities activity, although it may be reused or considered as a source of materials or energy for others. Waste may be solid as residential solid waste, liquids as industrial waste water, greywater, or gases such as dust, smoke, airborne (APWA, 1966).

The relationship between public health and the improper waste storage, handling and disposing is significant. People learned this by the hardest way, after suffering from rats and flies breeding and epidemic diseases that spread in the areas where the solid waste

were dumped and disposed off without soil covering layers. Furthermore, water pollution and soil degradation took place. For instance, the leachate contaminates the surface and ground water and the soil absorbs the toxic metals and ingredients from the waste (Wilson, 1977).

In the nineteen century, a big steps took place in this regards, for example, in New York city private sector participated in cleaning the streets and collection the waste, while in 1888 England prohibited the throwing of solid waste into ditches, rivers and water streams (Wilson, 1977).

2.2 Types of Solid Waste

It is the classification of waste depending on its generation source. Heterogeneous nature of commingled solid waste makes studying it not an easy job. The solid waste main types are:

a) **Residential or Domestic:** includes non-hazardous waste generated in households, commercial and business establishments and institutions that are disposed off.

b) **Commercial:** all municipal solid waste generated from business establishments such as stores, markets, office buildings, restaurants, shopping centers, and entertainment centers.

c) **Institutional:** waste originating in universities, schools, hospitals, prisons, research centers and other public buildings. As the source of this waste is the people and their activities, so its composition is similar to those from households.

d) **Construction and Demolition:** all solid waste generated from construction activities, dredging materials, tree stumps, and rubble resulting from construction, remodeling, repair, and demolition of homes, commercial buildings and other structures or pavements. The nature of this type of MSW depends upon the used resources in a given region or country for the purposes of construction. In the absence of adequate local ordinance, responsibility for the management of these wastes is invariably assumed to lie with the municipality.

e) **Industrial:** heterogeneous mixture of different materials generated during an industrial process. It may be gaseous, liquid, sludge, or solid. It's composition depends upon the natural resources, raw materials, markets, and manufacturing process.

f) **Agricultural:** the solid waste resulted from plant cultivation activities such trees trimming waste, grass, plastic house, and irrigation hoses (Vesilind and Rimer, 1981, Tchobanoglous et al., 1993).

2.3 Characteristics of Solid Waste

It is the identification of chemical, physical and biological properties of waste. Characterization is limited to residential, commercial and some industrial waste. Solid waste characterization is difficult process due to the limited number of samples that can be collected and analyzed, the large number of sources and the heterogeneous nature of solid

waste. As a result different schools for sampling procedures are adopted all over the world (Vesilind and Rimer, 1981). The main characteristics of solid waste are:

2.3.1 Physical Properties of Solid Waste

The main physical prosperities of solid waste are specific weight, moisture content, particle size, size distribution and field capacity (Vesilind and Rimer, 1981).

I. **Specific weight:** The weight of materials per unit volume lb/yd^3 or kg/m^3. Each waste component has its own specific weight. Compaction process can affect the specific weight, so the specific weight is reported for uncompacted waste or as found in the container. Specific weight depends on the geographical location, season of the year and the length of time in storage. Typical value of specific weight for delivered solid waste in compactor is 296.6 kg/m^3 (500 lb/yd^3) (Tchobanoglous, et al., 1993).

II. **Moisture content:** represents the amount of water in the waste. This is considered the major parameter in measuring the heat value of the solid waste, as the moisture content is higher; the lower is the heat or calorific value of the solid waste. Moisture content is measured as the difference in weight for an item wet and after dried in an oven at 105 ^oC. The typical data for the moisture content is between 15-50%. It varies from one place to another and from season to another. SW composition is main factor that affect the moisture content (Tchobanoglous, et al., 1993).

III. **Particle size and size distribution:** It is an essential term in material recovery especially with mechanical sorting machines like screens or magnetic separator. The average size for individual solid waste components is between 17 -20 cm (7 -8 inches). Also, it is important factor in designing waste collection using pneumatic system.

IV. **Field capacity:** It is the total amount of moisture that can be retained in a waste sample subject to the downward pull of gravity. This is important in the determining the leachate formation in the landfill, where the excess water will be released as leachate, other factors that affect the amount of leachate are the applied pressure and the degree of decomposition of the solid waste (Vesilind et al., 2002).

2.3.2 Chemical Properties of Solid Waste

The information about the chemical composition of the solid waste components is essential in determining processing and recovery options, especially heat recovery. The main chemical prosperities are ultimate and proximate analysis, fusing point of ash and energy content.

a) **Proximate analysis:** The determination of the combustible components in solid waste. It includes moisture content, volatile combustible matter, fixed carbon and ash (Vesilind et al., 2002).

b) **Fusing point of ash:** The temperature at which ash resulting from the burning of waste at 1100 – 1200 ^{o}C (Tchobanoglous, et al., 1993).

c) **Ultimate analysis of solid waste:** The determination of the percentage of Carbon, Nitrogen, Oxygen, Hydrogen, Sulfur, and Ash. Ultimate analysis is used to characterize the chemical composition of the organic matter in municipal solid waste. Determining chemical composition is necessary to achieve the optimum C/N in the composting treatment of solid waste, or to calculate the heat content (Vesilind et al., 2002).

d) **Energy content of solid waste:** It is determined by full scale boiler as colorimeter and laboratory bomb colorimeter or by calculations if the elemental composition is known. The moisture content directly affects the energy content because portion of the heat within the solid waste will be consumed to evaporate the moisture. When the solid waste is used as a feed stock or as a soil conditioner after its treatment, the essential nutrients and other elements should be determined.

2.3.3. Biological Properties of Solid Waste

Include the content of the organic fractions in the solid waste except the plastic, rubber and leather components. The main organic fractions are the oil, fat, water soluble substances as sugar and starch, cellulose, lignin and protein. Usually the organic fraction is degradable even though some fractions may take long time to degrade as lignin (Vesilind et al., 2002).

Biodegradability of the organic fraction of the solid waste is determined by the volatile solid content (VS) that is determined at a temperature of 550 ^{o}C. Degradation of the organic fraction is responsible for most of the odor produced from the solid waste degradations (Tchobanoglous, et al., 1993).

2.4 Composition of Solid Waste

It's the term used to describe the individual components that is included within a solid waste stream and their relative distribution usually based on percentage by weight. Solid waste composition is essential to design the treatment system, collection program, required tools and machines. In other words, knowing what materials are in the waste stream helps identify to what degree are valuable natural resources thrown away rather than reused, recycled or recovered to create other products, materials or energy (Vesilind et al., 2002). This can lead to important economic, environmental and social benefits, and improve our understanding of the environmental and health impacts of waste. Waste composition information can help develop waste minimization policies, target waste minimization programs and improve recycling schemes.

Solid waste composition usually includes organic fraction, paper and cardboard, plastic metals, glass, textile, rubber, hazardous materials and others. The solid waste composition varies from one country to another. One of the most important factors that distinguish the solid waste composition distribution is the income of the families, For example, the typical food waste percentage in low income countries, with an average income less than $ 750 per capita/year, is between 40-85%, while in the countries with an average income is between $750-$5000 the percentage is between 20-65%, and in the upper income countries the percentage is between 6-30% (EPA, 1989; Tchobanoglous et al., 1993).

2.5 Solid Waste Management

Refers to all the activities associated with the waste from its generation point till its final disposal in the landfill, these activities are divided into six main functional elements:

2.5.1 Waste generation

The word waste related with zero value items that either are thrown away or collected together for disposal. The rate of waste generation varies from time to another and from place to another, it depends on a set of complex factors, such as, types and patterns of consumption, household revenue, and lifestyles, regulations, climate and yearly seasons (Kaplan et al., 2009).

Predicting or determining the solid waste generation rate is very important for proper design of management process like number of workers, working time, collection route and frequency, collection vehicles and containers size. The generation rate depends on the type of the waste. Residential solid waste is represented as kilogram per capita per day (kg/capita. day) (METAP, 2005).

2.5.2 At source handling and storage

Includes the activities associated with the management of solid waste until its disposal in the storage containers that are collected later by collection services provider. It includes one or more of separation, storage, reuse or recycling (Tchobanoglous et al., 1993).

The space availability and the local regulations play main role for motivation of the source separation of solid waste. The fees or charge exemptions are directly influence the amount of generated solid waste, for example in Germany the citizen pay high charges for their unseperated solid waste, while they pay nothing for their separated glass, metal or plastic solid waste (Sweep net, 2010).

Attention and special requirements should be taken when SW stored at source, for example organic waste should not be stored for long time to avoid its degradation and odor

formation. More precaution should be taken to prevent contamination of stored SW with hazardous contaminants. The size and location of the storage container should be combatable with the quality and quantity of the separated solid waste.

2.5.3 Collection of solid waste

The functional element of collection includes not only the gathering of solid waste, but also the hauling of waste after collection to the transfer station or processing station, or landfill (Jaradat, 1999). Uncontrolled growth of population in developing countries in recent years has made solid waste management an important issue (METAP, 2005). Very often, a substantial amount of total expenditures is spent on the collection of solid waste by cities authorities. Optimization of the collection and transportation systems of solid waste is essential for effective solid waste management system. Collection process includes removal and transport of the solid waste to a disposal site (Jaradat, 1999).

In small city where final disposal sites are nearby, the waste hauling is not a serious problem. According to Tchobanoglous, et al. (1993) in large cities where the solid waste has to be hauled for distance longer than 16 km, the hauling process may be serious economic implications.

The collection process may be done manually by individuals who lift, carry, or roll the loaded containers or mechanically by using machines. The collection may be done by curbside collection services or hauling collection services using conventional and specially designed vehicles (Jang et al., 2009).

The hauling services classified into conventional mode and exchange container mode. The favorable time to collect the solid waste from crowded places such as commercial centers is early morning or late at evening, such arrangement aims to avoid the rush hours. The SW collection time can be categorized as the following:

a) Pickup Time:

Depends on the collection type, for conventional hauled mode it is the sum of time spent driving to the next container after an empty container has been deposited. This includes the time spent picking up the loaded container, and the time required to redeposit the container after its contents have been emptied. For exchange hauled container mode, it includes the time required to pick up a loaded container and to redeposit the container at the next location after its content has been emptied. On the other hand, the pickup time for curbside collection mode is the time spent loading the collection vehicle, beginning with the first container and ending when the content of the last container has been emptied in the collection vehicle (Tchobanoglous et al., 1993).

Haul Time:

Depends on the type of collection system, for hauled container mode, it represents the time required to reach the location where the contents of the container will be emptied. It starts when the container is loaded into the collection vehicle, continuing through the time after leaving the unloading location until reaching the deposition site. While for curbside collection mode, it refers to the time when the collection vehicle is filled, continuing through the time after leaving the disposal site until the vehicle reach the place where it

start collecting the container again. Haul time does not include any time spent at the disposing location (Tchobanoglous et al., 1993).

b) At Site:

The time spent at the vehicles emptying place, and includes the time for unloading the vehicles plus the waiting time.

c) Off-Route:

It is all the nonproductive time spent during the collection process; this does not include the necessary activities that are done to maintain the collection process such as the maintenance and morning check or time lost due to unavoidable congestion (Tchobanoglous et al., 1993).

The quantity and quality of the generated solid waste are main factors in designing the collection programs. For example, in places where solid waste generation rate is high, using 8 m^3 containers minimizes the required collection frequency. On the hand, the organic fraction of solid waste should be collected as soon as possible to avoid its degradation.

The amount of SW that is picked up or collected always less than the amount that is generated, it varies between 4 – 15%. The difference depends on the efficiency of the collection process, cost and services time, personal and natural factors such as evaporation, degradation, or donation to charitable agencies (Vesilind et al., 2002). Analyzing all the SW components is essential to determine the proper collection options, these options are as the following:

- **Route type:** aims to collect maximum amount of SW with minimum collection time and efforts, it is determined by trial and error. With time the operator can gain the enough expertise to perform and determine the route professionally.
- **Vehicle type and size:** it depends on the solid waste quantity, quality, land topography and status of streets and neighborhoods.
- **Crew size:** because some activities in SW management are done manually, the crew size is important to optimize productivity. It depends on the collection machines, techniques and tools. (APWA, 1966).
- **Length and number of shifts**: Shift length arrangement aims to get full loads in collection vehicle, such arrangement must be flexible and assessed from time to time. Shift productivity should be taken in consideration when determining the demand for extra shifts (Vesilind et al., 2002).
- **Public or private operator:** the choice of including the private sectors in SW management activities aims to minimize the cost of the collection process with maximum offered services.

2.5.4 Processing and Recovery of Solid Waste

Includes chemical or/and physical waste transformations and materials separation operations to recover valuable resources from the mixed solid waste or the energy heat. The aims of these operations are benefiting from the solid waste economically or environmentally. Under this term come all the processes done on the waste before its final disposal. For example, collection centers for solid waste, Material Recovery facility (MRF)

or any physical actions done on the waste to classify it, or to minimize its size and volume (Vesilind et al., 2002). The typical issues with respect to processing and recovery are:

a) Determining the proper time and place for the processing.

b) Establishing priorities according to the spaces availability and financial support.

c) Identifying the market for recovered materials and/or energy, and to assess the impact of market stability on the solid waste management system.

2.5.5 Transfer and Transportation

It is a two step process, where the first one is transferring the solid waste from smaller collection vehicle to larger one, and the second process is transporting the solid waste usually over long distance, to final disposal site. The transfer process usually takes place at a transfer station. Such system is considered when solid waste hauling distance is too large so the direct hauling is no longer feasible, or when the processing centers or disposal sites are sited in remote location (Vesilind et al., 2002). In general, the hauling process should fulfill the minimum hauling requirements on the roads such as covering the waste, vehicle should be design for highway traffic, the load should not exceed the allowable limit and the vehicle path should avoid the traffic jam as possible.

2.5.6 Disposal

The destruction and/or final destination of solid waste, by other words it is the ultimate fate of the solid waste (Wilson, 1977). The traditional approach to municipal waste disposal has been heavily dependent on landfills (Wassermann et al., 2005). However, the increasing scarcity of available landfill sites, their capacity limitations, especially in the urban centers

and the rising awareness of the environmental hazards caused by such disposal practices, as well as the more restrictive environmental regulations on landfill operation and maintenance, have all motivated the researchers to develop techniques to minimize the side effect of dumping the waste, and alternatives to recover the materials and energy from the waste. Modern landfill sites have developed from uncontrolled dumping sites to be an advanced treatment and disposal option designed and managed as engineering projects. In addition, modern purpose-built landfill sites normally incorporate a system for the extraction of landfill gas (arising from the decomposition of bio reactive wastes), from which energy can be recovered (METAP, 2005).

Wilson (1977) considered the site selection process a sensitive task, where it requires technical engineering competence, special attention to the economical, social and political aspects of land uses planning. For example, the site should comply with the local authorities' requirements in term of land uses, and the location should have the acceptance of the public and local society. On other hand, all the engineering and economical aspects should be considered in the site such as climate, topography, solid waste transportation costs and operational costs. The objectives of the minimum requirements for landfill operation are:

- To ensure that all waste is disposed of in an environmentally and socially acceptable manner.
- To ensure that the disposal operation is acceptable to those whom it affects.

To develop solid waste management, all its functional elements should be considered because they affect each other, Figure (1) shows the relations between the solid waste elements, and how they are connected to each others.

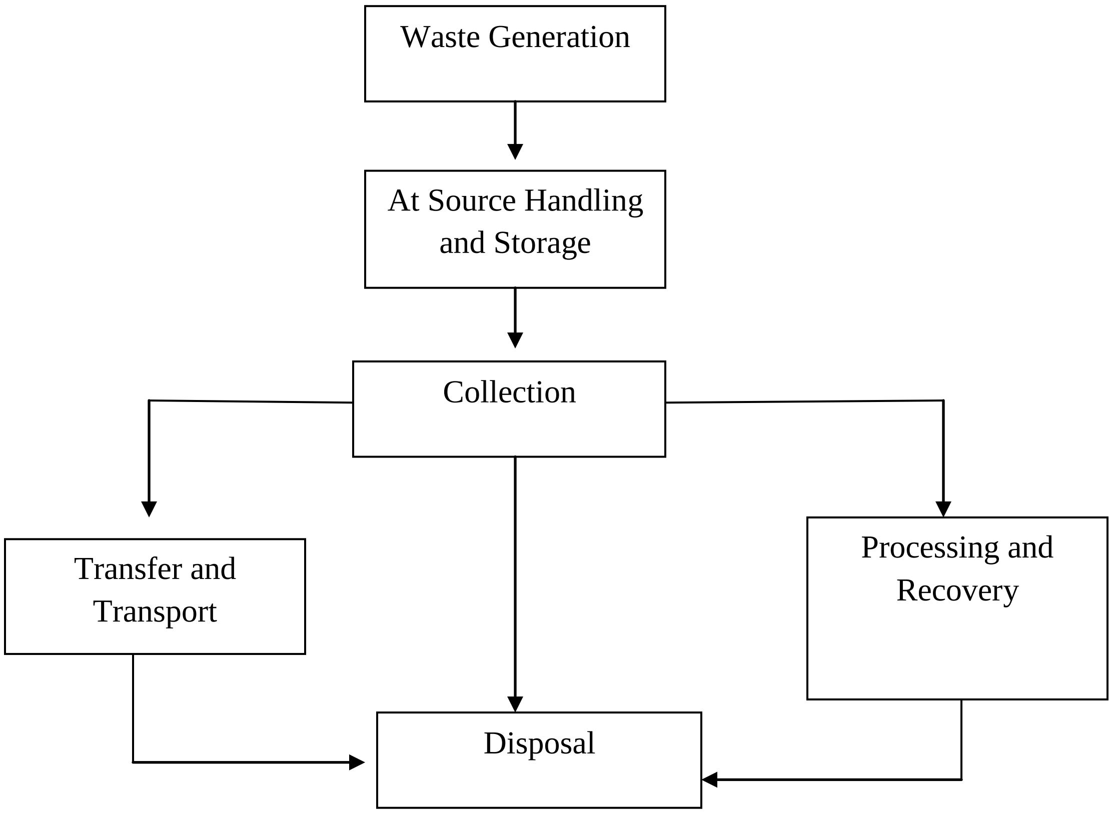

Figure (1): Functional Elements of Solid Waste Management, Tchobanoglous, et al., (1993).

2.6 Integrated Solid Waste Management

Integrated Solid Waste Management (ISWM) means planning effectively and in sustainable manner. This requires an understanding of the needs and preferences of a wide range of stakeholders regarding service delivery, costs and corresponding social impacts (Otegbeye et al., 2009). It is a comprehensive waste prevention, recycling, composting and disposal program. An effective ISWM system considers how to prevent, recycle and manage solid waste in ways that most effectively protect human health and the environment. ISWM involves evaluating local needs and conditions, and then selecting and combining the most appropriate waste management activities for those conditions. The major ISWM activities are waste prevention or source reduction of solid waste, recycling, composting, energy recovery and disposal in properly designed, constructed, and managed landfills. Each of these activities requires careful planning, financing and operation (Jang et al., 2009).

2.6.1 Source reduction

Means reducing the amount of waste entering the MSW stream by redesigning products or patterns of production or consumption. Source reduction is the first defense line against solid waste impacts. It will minimize the cost and efforts spent for collection and other processes which will save cost and time (EPA, global warming, 2002).

Solid waste source reduction starts from the primary industrials steps and ends by altering consumer behaviors. For instance, modification of the manufacturing process to minimize the waste production, and/or produce more durable goods and increase life cycle of the products can reduce the generated solid waste significantly (EPA, global warming, 2002).

2.6.2 Reuse

Wilson, (1977) defined the reuse process as using a component of MSW in its original form more than once. For instance, refilling a glass bottle that has been returned or using a can to hold nuts. Such behaviors extend the life cycle of the materials, by other words instead of throwing the item directly after using it but to find another use for it.

2.6.3 Recycling

It is processing a commingled solid waste by a way that recyclable materials are collected and used as raw materials for new products (Li et al., 2010). Recycling includes collecting recyclable materials, separating materials by type, processing them into a form that can be sold as scrap material, and purchasing and using goods made with reprocessed materials. Recycling process can be accomplished manually or/and mechanically (Al-Khaldi, 2002). The potential benefits from recycling are:

- Prevents potentially useful materials from being landfilled or combusted.
- Allows disposal capacity to be preserved.
- Saving energy and natural resources.

By definition, recycling does not occur until someone transforms or remanufactures the material to usable or marketable product or material. Markets availability for recyclables and recycled materials are essential to complete recycling process cycle, without such markets there is no recycling (Al-Khaldi, 2002). Marketing recyclable and recycled products involves, determining the possible uses of the end product, identifying potential

markets and developing a collection and transfer system (Vesilind et al., 2002). The target materials for recycling are paper, cardboard, plastic, metals, and glass (MoEnv, 2010).

2.6.4 Solid Waste Energy Recovery

Process that aims to use or extract the heat that is included in the solid waste by various techniques, directly as incineration or combustion, or indirectly by Pyrolysis, and refuse derived fuel (RDF) where the waste derived first to fuel (Zhao et al., 2010).

The heat content is defined as the number of heat units evolved when unit mass of material is completely burned and is measured in joules per gram (J/g) or British Thermal Units per Pound (Btu/lb) (Abu-Qudais and Abu-Qdais, 2000).

The heat content of solid waste is a function of many parameters, namely, physical composition of the waste, moisture content and ash content.

Thermal treatment of solid waste with waste to energy (WTE) has a number of advantages. For example, short time of treatment, possibility of treating extremely dangerous and/or hazardous waste, possibility of effluent gas control and possibility of utilizing heat released by the oxidation process usefully. On the other hand, several problems related to human health coming out from WTE operations, such as safety requirements, side products and its state of matter (effluent gases, waste water, solid residues), all of these create a big debate about WTE process and make it concern of all people specially who live near these facilities (Pavlas et. al., 2010).

There are many empirical models developed to predict the heat content in solid waste such as Conventional, Dulong's, Traditional, and Bento's Models, these models depend on

physical composition of the solid waste, ultimate analysis and proximate analysis of the solid waste (Abu-Qudais and Abu-Qdais, 2000).

Elemental composition of the waste is the most crucial parameter for determining thermal energy. Over or under estimation of solid waste heat content will result in poor performance of WTE plants. Therefore it is preferred to do both, calculations and direct measurements using bomb calorimeter to evaluate the heat content in the MSW (Menikpura, and Basnayake. 2009). Table (1) shows some models used to calculate the heat content.

Table (1): Used Formulas to Estimate the Heat Content.

Physical Composition Analysis	**Ultimate Analysis**	**Proximate Analysis**
Conventional model $\mathbf{H_n=88.2R+40.5\ (G+P)-6W}$ H_n: net caloric value (kcal/kg) R: %weight of plastic on dry base G: %weight of garbage on dry base W: % weight water on dry base P: %weight of paper on dry base	Modified Dulong's model $\mathbf{(HHV)= 145C + 610(H- O/8) + 40S + + 10N}$ HHV: High heating Value in (Btu/lb) C: is Carbon percentage H: is Hydrogen percentage O: is Oxygen percentage S: is Sulfur percentage N: is Nitrogen percentage	Traditional Model $\mathbf{H_n=45B - 6W}$ B: combustible volatile matter W: % by weight of water on dry base
Kahn and Abu Ghrarah Model $\mathbf{H = 23[F+3.6(PA)]+160\ (PL)}$ H: heat content (Btu/lb) F: % of organic by weight PA: % of paper by weight Pl: % of plastic by weight	Dulong's model $\mathbf{H_n = 81C + 34.2[H - O/8] +22.5 S - - 6[9H + W]}$ H_n: net caloric value (kcal/kg) W: water, percent on dry basis	

Abu-Qudais and Abu-Qdais, (2000)

According to Buah et al. (2007) WTE plant contributes in minimizing global warming phenomena by the following scenarios:

1- For every Megawatt of electricity generated through the combustion of solid waste a Megawatt of electricity from conventional coal or oil-fired, power plants is avoided, creating a net savings of emissions of greenhouse gases as carbon dioxide.

2- A modern municipal WTE facility has its own recycling and separation systems and it separates ferrous and/or nonferrous metals. This is more energy efficient than mining virgin materials for the production of new metals such as Steel or Aluminum. As a result, there is a significant energy savings and additional avoidance of greenhouse gas emissions.

3- When a ton of solid waste is delivered to a WTE facility, the methane that would have been generated if sent to a landfill is avoided. While some of this methane could be collected and used to generate electricity, some would not be captured and would be emitted to the atmosphere. Zhao et al. (2010) mentioned that as methane is a potent greenhouse gas twenty three times more potent than carbon dioxide .The process that produces methane should be well controlled, and it should not allowed to be escaped to the atmosphere. In any way such control is easy achievable by fixing a well collection network and flare or storage tanks to collect the emitted methane gas.

2.6.4.1 Incineration:

Includes waste treatment process that involves the combustion of organic substances contained in waste materials which includes food, paper and cardboard, textile, leather, rubber and plastic. The incineration outputs are ash, effluent gases, and heat. The ash is mostly formed by the inorganic constituents of the waste, and may take the form of solid lumps or particulates carried by the flue gas. The flue gases must be cleaned of gaseous and particulate pollutants before they are dispersed into the atmosphere. Modern municipal incinerator designs include a high temperature zone, where the flue gas is ensured to sustain a temperature above 850 °C for at least 2 seconds before it is cooled down, this ensures breaking down dioxin gas (Zhao, L. et al., 2010).

For every ton of waste landfilled, greenhouse gas emissions in the form of carbon dioxide increases by at least 1.3 ton, while only 1 ton of carbon dioxide is produced per one ton of solid waste incinerated (Pavlas et al., 2010). The older method of combustion sometimes led to problems such as fly ash containing toxins escaping and contaminating nearby areas, or production of a toxin residues. However, modern waste incineration techniques are much more thorough and more self-contained and are no longer a contamination risk (Menikpura, and Basnayake, 2009). The main disadvantages of incineration include production of large flue gas volumes, hazardous waste streams associated with the fly ash and a poor public image. Finally MSW dumping in landfills is comparatively cheaper than incineration (Kaplan et al., 2009).

2.6.4.2 Pyrolysis:

It is a thermal processing of solid waste in absence of oxygen by indirect heating using external source of heating. Pyrolysis is an endothermic reaction, in this process the organic

fraction of solid waste is converted into gaseous, liquid and solid fuels, it is also called as destructive distillation (Tchobanoglous et al., 1993). In recent time it has been used in many countries as a source of fuel production from solid waste with many techniques to perform the process.

Usually the inert materials such as metal and glass are removed prior the process to increase the output heat. It is important to understand that Pyrolysis of waste dose not stand alone, but is generally followed by other process such as gasification and liquefaction to maximize the revenue.

Typical yields resulting from the process are 55% oil, 35% black carbon and inorganic and 10% gas (Pavlas et al., 2010). Obviously, the process is unlikely to be adopted as a refuse disposal alternative by local authorities in the short term, but in the long term it should be seriously considered as a source of energy (Buah et al., 2007). Economics also play a significant role in the eventual success of the process. Application of technology will require a great deal of attention to details regarding the economics of the materials balance and the desire products for specific application (Tchobanoglous et al., 1993).

2.6.4.3 Gasification:

The gasification treatment is a new harmless treatment technology. It is characterized with quick processing speed, violent chemical reaction, large reduction of capacity, controlled combustible gas, low exhaust volume and high energy utilization, as well as the inhibition of the formation of toxic dioxins (Vesilind et al., 2002).

The main gases that are produced are CO, CO_2, CH_4 and H_2. So gasification can further realize the reduction of capacity and quantity of MSW (Tchobanoglous, et al., 1993). The MSW gasification is an endothermic process, and heat has to be supplied continuously for this process to ensure the reaction temperature.

In general, MSW gasification includes four steps. The first step is the evaporation of the moisture at a lower temperature up to 200 ^{o}C. The second step is a thermo-chemical decomposition of MSW with the production of tar, char and volatiles, and this step termed primary Pyrolysis. The third step includes reaction of volatiles with oxygen. The last step includes mainly some reduction reactions (Belgiorno et al., 2003).

According to Belgiorno et al. (2003), when the heating temperature is ranged between 700-1000 ^{o}C a relatively high level of hydrocarbons is produced compared to heating in the range of 1200 – 1600 ^{o}C which produces higher proportion of CO and H_2 with few hydrocarbons in the product gases.

2.6.4.4 Composting:

Composting is the transformations of raw organic materials into biologically stable, humic substances suitable for a variety of soils and plant uses (Tchobanoglous et al., 1993). Essentially, composting is a controlled decomposition, in which natural breakdown process occurs when organic residue comes in contact with soil. It can happen aerobically or unaerobically. Aerobic composting is the most efficient form of decomposition and produces finished compost in the shortest time (Vesilind et al., 2002).

Composting is a microbial mediated process that requires a specific set of chemical and physical conditions. Compost can be produced on a variety of levels ranging from home

composting to large commercial operations (Li et al., 2010). Compost can be used in agriculture, and horticulture production, as well as landscaping, home gardens, and remediation of contaminated sites. Compost can be introduced to reduce or eliminate organic waste landfilling.

2.7 Solid Waste Management in Jordan:

2.7.1 Previous Studies

Different studies indifferent periods have dealt with solid waste management system in Jordan. Abu Qudais. (1987) evaluated the solid waste management in Irbid city, and concentrated on the collection problems which formed the highest portion of the cost of solid waste management process at that time. He recorded that the used solid waste management system was ineffective, unsatisfactory and costly.

In his study, two scenarios to transfer the generated solid waste in the city were analyzed, the first one was to keep using Al-akeder landfill that is located 26 km to the east of Irbid city, but to build new transfer station in Huwara region and to pick the solid waste from there and transfer it to Al-akeder landfill. This scenario saves around 30% of the solid waste collection activities.

The second scenario was to build three transfer stations and three landfills which will be used to dump the waste from the transfer stations. Moreover, waste composition and generation rates were analyzed. The recorded solid waste generation rate was 0.78 kg per capita per day with food organic fraction of 70% from the total generated waste. The second scenario was recommended to minimize the cost of the waste collection.

Furthermore, distribution more solid waste containers and to do further analysis to the routes of waste collection were suggested.

Several studies in different periods identified the physical and engineering prosperities of different types of MSW in Amman city. Aranki (1987) reported that about 260 tons / day of commercial wastes where generated in Amman city at a rate of 0.3 kg/ capita per day, around 54% of this amount was food waste, 2.3% is plastic and 32.9% paper and cardboard. The overall density was 141 kg/m^3. Moisture content ranged from 32.2 – 78.2%.

Zeyadeh (1987) studied the house hold refuses generated in Amman city. He found that 0.4 kg/capita per day is an average generation rate of house hold refuses and the total produced residential waste was 400 tons per day. He recorded that 61.3 % of the total produced waste was organics, 15.6%, 8.3% and 3.6% were paper, cardboard and plastic, respectively. The overall moisture content was 56.4%. Regarding the moisture and the quantities of compostable fraction, Zeyadeh suggested that converting these waste into compost or animal feed are suitable alternatives.

In 1995 the Royal Scientific Society (RSS) conducted a study focusing on the environmental impacts of Rusaifeh landfill, where the commingled MSW of Amman and Zarqa governorates were dumped. The total amount of MSW dumped in the landfill was recorded as 1200 tons/day. The generation rate was calculated as 0.93 kg/capita per day with 40% moisture content. Waste composition analysis showed that 53%, 17%, 8%, 10% and 12% were accounted by organics, papers, metals, glass and plastics, respectively. The

expected amount of leachate was 160 m^3/day, which may reach the ground water aquifers within 15-20 years.

Fichtner Consolidated Consultants (FCC) (1996) carried out a feasibility study for recycling and composting the MSW of Amman city. Different options of composting methods have been evaluated with a combination of recycling, incineration and landfilling. The excepted amount of compost ranged between 153 and 420 tons per day, and about 100 Megawatts per year of electricity production was expected. The results showed that SW composting is not feasible and would have required subsides of 7.35 JD / ton, because animal manure is cheaper and favorable. Moreover, manure compost is more environmentally safe. The analyses of waste composition showed that organics, plastic, paper, cardboard, textile, metals and glass accounted for 44%, 13.2%, 7.74%, 2.96%, 4.72%, 2.42% and 1.42%, respectively.

Cabinet Merlin Consulting Engineers (CMCE) (2002) prepared a solid waste management plan for Amman city. The study aimed to maintain the overall urban environmental quality and the public hygiene. MSW composition were organics, plastics, textiles, paper and cardboard and glass accounted for about 41.4%, 14.2%, 4.2%, 12.6% and 1.8% respectively of the total produced MSW. The average density was 184 kg/m^3 with average moisture content 48.4%. The calculated net calorific value for the raw MSW was 1,770 kcal/kg at wet base, while it was 4,177 kcal/kg at dry base. The generation rate of MSW was calculated at 0.83 kg /capita per day.

The main outputs of the study were the design of new sanitary engineered landfill as a short term, and develop plan for MSW with 25 years life time to receive the MSW from Amman, Zarqa and part of Balqa governorates. The expected amount of leachate produced in the new landfill was approximated about 1,250 m^3/day as maximum in winter, and 620 m^3/day as a maximum in summer. In the short term, CMCE (2002) has defined and recommended the following actions:

- Build new landfill in Al-Gabawi.
- Reduce the cost of transportation by construction a network of transfer stations.
- Rehabilitate Al-Rusaifeh landfill.
- Implement an alternative treatment of medical waste by incineration to avoid this waste to reach the non hazardous water.

In the medium term, CMCE has recommended recycling and bio conversion (either by composting or by methane production) as MSW treatment options with landfilling.

The long term development plan recommended implementing an energy recovery system by incineration. The study did not identify the expected amount of Methane gas that may be produced by anaerobic degradation within the new landfill.

In 2009 Ministry of Environment with cooperation with Royal Scientific society (RSS) conducted study to determine the quality and the quantity of solid waste dumped in Al-Akeder, Humra and Al-Husseniat landfills. Furthermore, samples from ground water wells located near theses landfills were analyzed to assess the degree of pollution due to landfills leachate if it is exist. Risk maps of groundwater pollution were done using GIS to give indicators about the sensitivity of the landfills geological layers toward pollution. Finally

the study recommended remediation action plan to protect the ground water from leachate pollution. Table (2) summarizes the solid waste compositions which were analyzed by different studies that were performed at different periods. These studies do not have the same solid waste components so the main components only are included in the table. Moreover, Table (3) compares the composition of solid waste which is generated in Jordan with the ones that are generated in different countries.

Table (2): Main Components of SW Composition for Different Studies.

Study / Composition %by Weight	MoEnv. and RSS (2009)	JUST (2007)	CMCE (2002)	Fichtner (1996)	RSS (1994)
Organics	38.8	52.2	51.4	44.0	53.0
Paper and Cardboard	12.2	12.7	12.6	10.6	17.0
Metals	3.8	1.4	3.1	2.4	8.0
Plastics	17.1	17.1	14.2	13.2	12.0
Glass	2.6	2.5	1.8	1.4	10.0
Textile	8.5	-	4.2	4.7	-
Rubber and Leather	1.5	-	3.0	-	-
Hazardous waste	0.1	-	0.1	-	-
Miscellaneous	15.4	14.1	9.6	23.6	0.0

Ministry of Environment, (2009)

Table (3): Comparison of Jordanian Solid Waste Contents with other Countries.

Waste Composition	**Jordan**	**Asian Countries**	**UK**	**USA**
Organic	50-68	75	36	20
Paper	5-10	2	31.2	43
Metal	3-6	0.1	5.3	7
glass	2-5	0.2	3.8	9
Plastic	4-6	0.1	5.2	5

Al-Ansari A. et al. (2005)

According to the department of statistics, Jordan has a population of about 6.1 million people (January, 2011) most of the citizens distributed in the capital Amman and the northern western parts. The population growth rate for the last six years was 2.2%. 82.6% of the citizens live in urban areas while the remaining 17.8% live in rural areas. Jordan is classified by the World Bank as a lower middle income country. In the year 2006, the per capita share from gross domestic product (GDP) was 1,785 JD (US$ 2,514). According to the Sweep net country report (2010) the total expenditure on solid waste management in Jordan for the year of 2006 was about 32.62 millions JD. GAM alone expended around 15.29 millions JD, while the remaining municipalities and independent institutions expended 17.33 millions JD.

3 METHODOLOGY

3.1 Introduction: Zarqa City

Zarqa city is located to the north east of Amman, and to the south of Al Mafraq Governorate. According to the GIS Department at the Municipality of Zarqa, the area of Zarqa governorate is 4080 km^2, while Zarqa city area is 65 km^2. The population in the governorate is one million while in Zarqa City is about 470,760 persons (Department of Statistics, 2010).

Zarqa's climate is hot and dry during the summer, and cool and rainy during the winter. The Zarqa Governorate is around 600 m above sea level, and receives average precipitation of 144 mm/year. For administrative purpose, for solid waste management activities Zarqa city has been divided into 9 districts as shown in Figure (4). The general considered procedure to identify and analysis the current MSW management practice were as the following:

1. Interviews with the environmental management personals in Zarqa municipality. These interviews aim to collect information related to the solid waste management process in the city.
2. Samples of solid waste at transfer station were analyzed to find there composition using the quarter method. A pile of solid waste was mixed and divided to quarters and then one quarter was chosen and mixed then divided into quarters again till the pile size became less than one hundred kilograms. It has been found that the measurement made on samples of up to 90 kg are not significantly different from those made on samples of up to 765 kg (Tchobanoglous et al., 1993, Vesilind and

Rimer 1981). After that the chosen pile was analyzed and the composition was determined. During sampling process the source of the solid waste was taken into account, to ensure that samples were taken to cover all Zarqa districts. A comparison between Zarqa waste composition and the available waste composition received in the Al- Husseniat, Humra and Al Akedar landfills were presented.

3. Solid waste density (ρ) was measured by weighting the content of plastic drum with specific volume. After filling the drum, it dropped down for 3-4 times from a high of 50 cm then the new space was filled again. Five replicate samples were weighted (jaradat, 1999). Then the density was determined by the following equation:

   Density (ρ) = weight of solid waste (kg) ÷ volume of solid waste in m^3. (3.1)

   Furthermore, moisture content was determined by weighting three samples, then drying it in an oven at 105°C, after that the sample was cooled and weighted again and the moisture content is calculated as the following:

   % Moisture content = [(Wet weight – Dry weight) x 100%] ÷ Wet weight (3.2)

4. Monthly weights of Zarqa's solid waste that transferred to Al-Gabawi landfill were found for the year of 2010, and then compared with the generation rate for Amman and Rusaifeh cities. These records were obtained from Al-Gabawi landfill management. After that, solid waste forcasting for Zarqa city till the year of 2030 was done.

5. Determination of the heat content of the degradable organic fraction of the solid waste (paper and cardboard, plastic, wood, organics and textiles) using the ultimate analysis and applying different formulas to calculate the heat content.

6. Process and operations done at the site of transfer station were described and analyzed from different aspects, like working hours, number of works and number and types of machines.

7. Field work for observations and data collection. For example, determination the streets cleanness, joining the compactors teams in there solid waste collection route to measure the containers emptying time.

8. Determination of different solid waste service indicators such as Number of Service regions, Population served per worker, Population served per vehicle, Ratio of workers to inspectors, cost of collection of one ton of the waste and adequacy of solid waste collection service using a community effect index (CEI) (Vesilind and Rimer, 1981). CEI can be calculated based on the streets cleanliness, by giving a rate to each street starting from 100 for a very clean street with no visible litter and reaching zero for extremely unclean street with scattered trash. After that 5-10 points may be deducted from the rate given to the street due to the presence of certain conditions, such as littered vacant lots or abandoned vehicles, for example CEI is calculated by the following formula:

$$CEI = \sum_{i=1}^{N} \frac{(S-P)_i}{N} \qquad (3.3)$$

Where:

S: the street cleanliness rating given based on the streets inspection process

P: presence of special conditions which leads to deducting of 5-10 points for each condition from the street rating

N: total number of inspected street

9. Distribution of questionnaires aiming citizens, commercial sectors, both people and commercial sectors are selected randomly from all over Zarqa districts. The questioners originally were developed with cooperation with team from Ministry of Environment, Zarqa Municipality, GAM and USAID under project for public awareness, then a modification to these questioners were done to comply with the objectives of this study. The questioners aimed to identify the behavior of the people, measure their satisfaction towered the services offered by Zarqa municipality and find out their willing to cooperate with the municipality with relevant to SWM. One more questionnaire was developed and distributed randomly aiming the municipality workers to measure their satisfaction and the difficulties that they face during duty time, its results were the basic guideline for this study. The total number of distributed questioners were (280) two hundreds eighty. The sample size was calculated using the following formula and procedure (Morris Hamburg 1985).

$$N = \frac{t^2}{m^2} \times p(1 - p) \qquad (3.4)$$

Where:

N = required sample size
t = confidence level at 95% (standard value of 1.96)
p = estimated prevalence of malnutrition in the project area, it is used to be 0.5 when no previous studies or approximations are available.
m = margin of error at 6% (standard value of 0.06)

N= $1.96^2 \times 0.5\,(1-0.5) / 0.06^2 = 266.78 \approx 267$

The sample is further increased by 5% to account for contingencies such as non-response or recording error so the total number were 280 questioners. Then the results of questioner are analyzed. The Figures (2, 3 and 4) show the location of Zarqa governorate in Jordan and the location of Zarqa city within the governorate and the Zarqa districts, respectively.

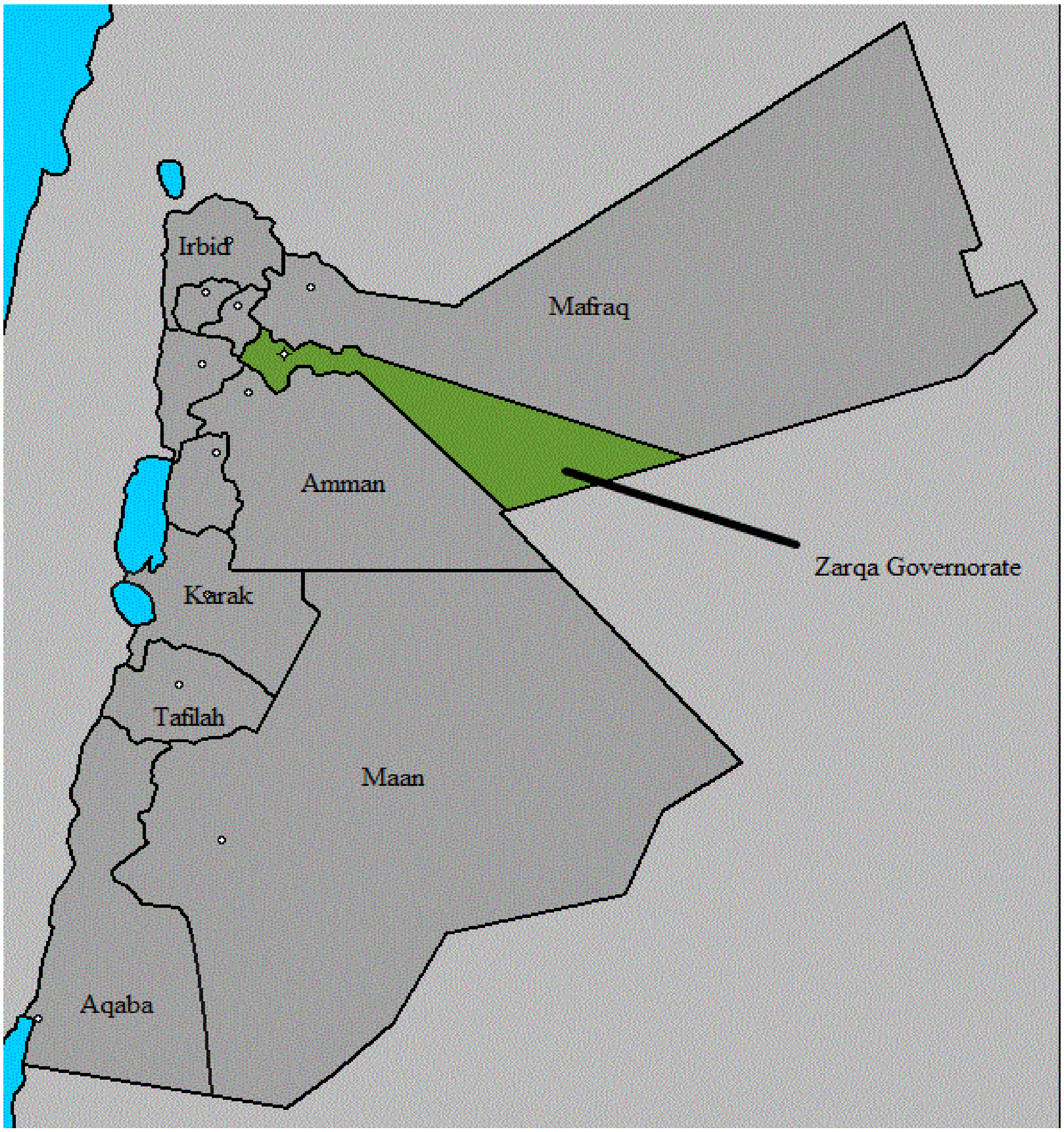

Figure (2): Map of Jordan Shows the Location of Zarqa Governorate (Ministry of Municipal Affairs).

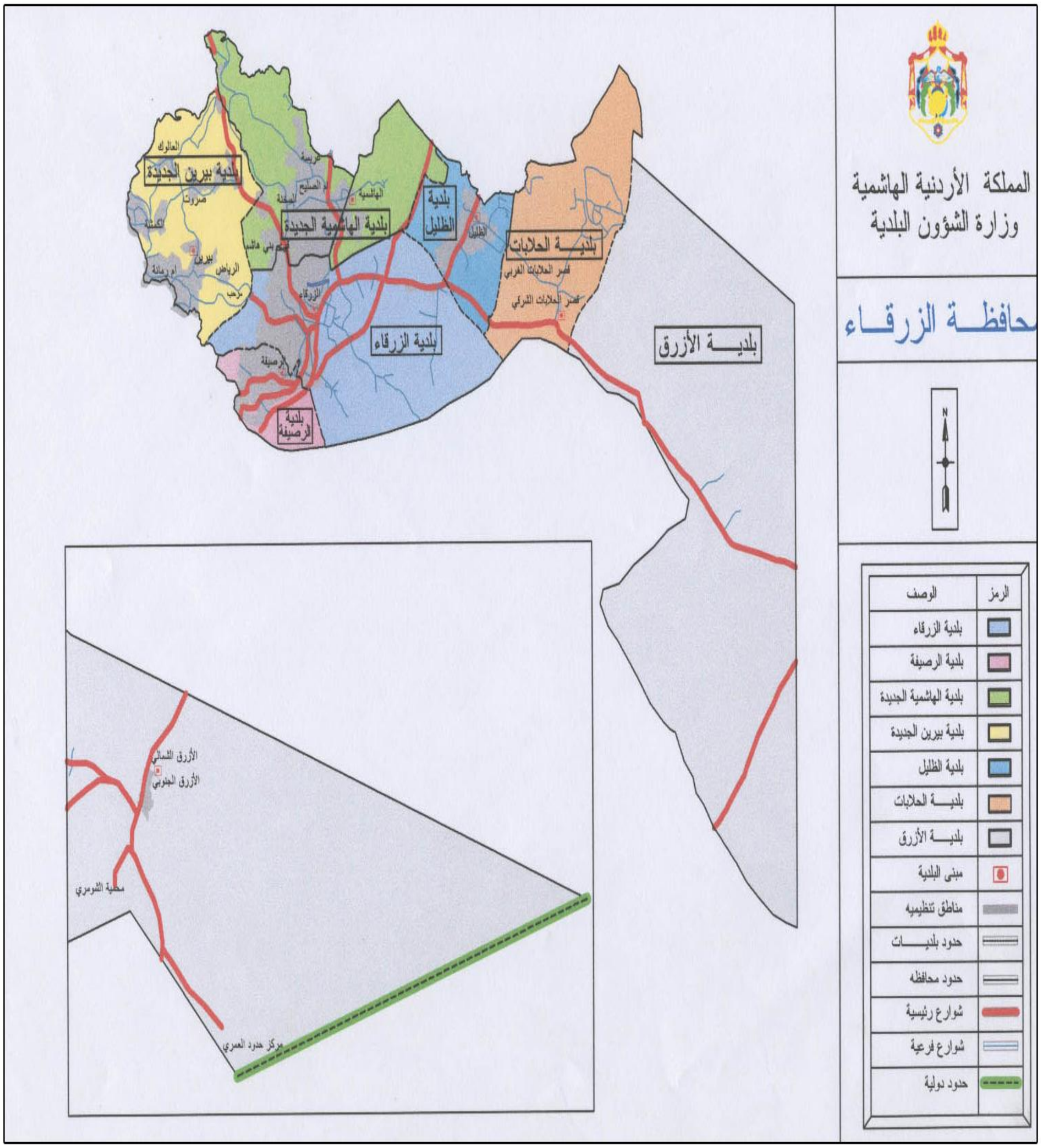

Figure (3): Zarqa City location within Zarqa Governorate (Ministry of Municipal Affairs).

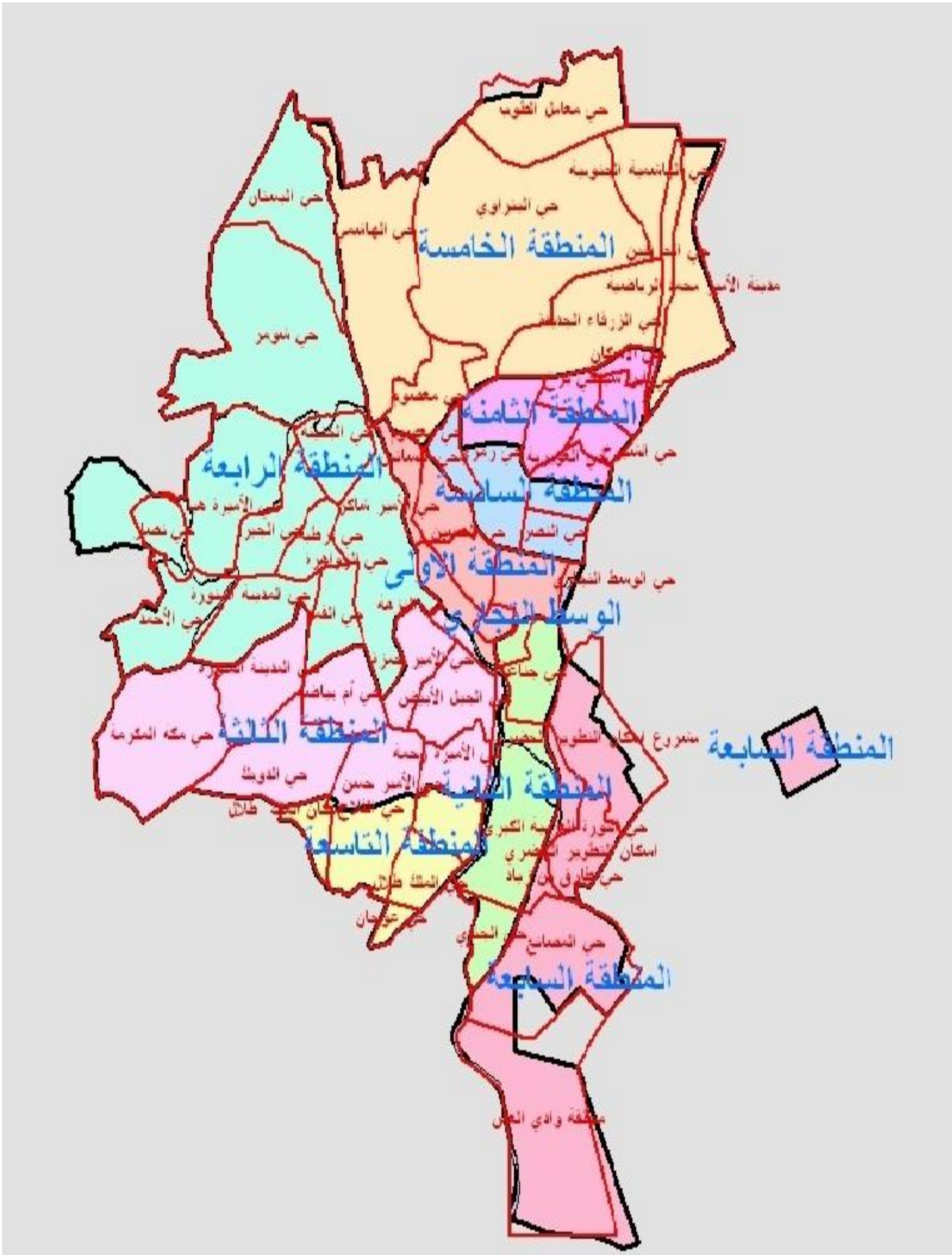

Figure (4): Solid Waste Services Districts (GIS Department - Zarqa Municipality).

4 RESULTS

4.1 Population of Zarqa City and Solid Waste Generation Rate

Zarqa municipality was established in 1928, the first settlement in the city was in 1908 when Chechen tripe had the permission from Ottoman governor to own the land. Then the population size has quickly grown. In the recent days and due to high concentration of factories and military camps, the city witnessed a great immigration movement. Nowadays, Zarqa population is more than 470,000 persons. Table (4) shows the predicted population numbers of Zarqa City between years of 2010– 2030. The predicted population number was calculated depending on the Zarqa population for the years 2000, 2005 and 2010 that were obtained from department of statistics, after that using different increase rates the population number was calculated. The rate of population increases K_g, K_a, K_d which are geometric, arithmetic and declining increase rates respectively, and Z constant were determined using the following relationships (Clark et al., 1977).

$$Ka = \frac{Y_2 - Y_1}{T_2 - T_1} \quad (4.1)$$

$$Kg = \frac{\ln Y_2 - \ln Y_1}{T_2 - T_1} \quad (4.2)$$

$$K_d = (\ln \frac{Z - Y_2}{Z - Y_1}) / (T_1 - T_2) \quad (4.3)$$

$$Z = \frac{2 \times Y_0 \times Y_1 \times Y_2 - Y_1^2 (Y_0 + Y_2)}{Y_0 \times Y_2 - Y_1^2} \quad (4.4)$$

Where:

K_g, K_a, K_d: geometric, arithmetic and declining increasing rates, respectively

Y_0, Y_1, and Y_2: populations number at time 0, 1, 2

T1, T2: time one and time two

Z: Coefficient to calculate K_d

Table (4) summarizes the population forcasting results using the above mentioned increase rates, and then the average number of population was considered to be the future population number as shown in Figure (5). After that solid waste generation rate was predicted. First, the current SW generation was calculated based on the current population number and the current amount of SW that is transferred to Al-Gabawi landfill, where it's found to equal 0.635 kg per capita per day. Then the SW generation rate has been increased by 3.3% annually based on Sweep net (2010) report.

Table (4): Population and Solid Waste Forcasting for Zarqa City for the Years 2010 – 2030.

Year	2.2% Annual Increment	Geometric Method k_g=0.0259	Arithmetic Method k_a= 88466	Declining Rate Method k_d=0.6466	Long Term Method (S Curve)	Average No of Population	Generated SW Based on Ave. Population with 3.3% Annual Increment
2010	470,763	470,763	470,763	470,763	470,763	470,000	291
2015	480,340	535,022	512,333	486,862	-	503,640	368
2020	490,907	609,040	554,667	499,067	-	538,420	400
2025	501,707	693,298	597,000	507,901	-	574,977	428
2030	512,745	789,212	639,333	514,295	529,828	597,083	446

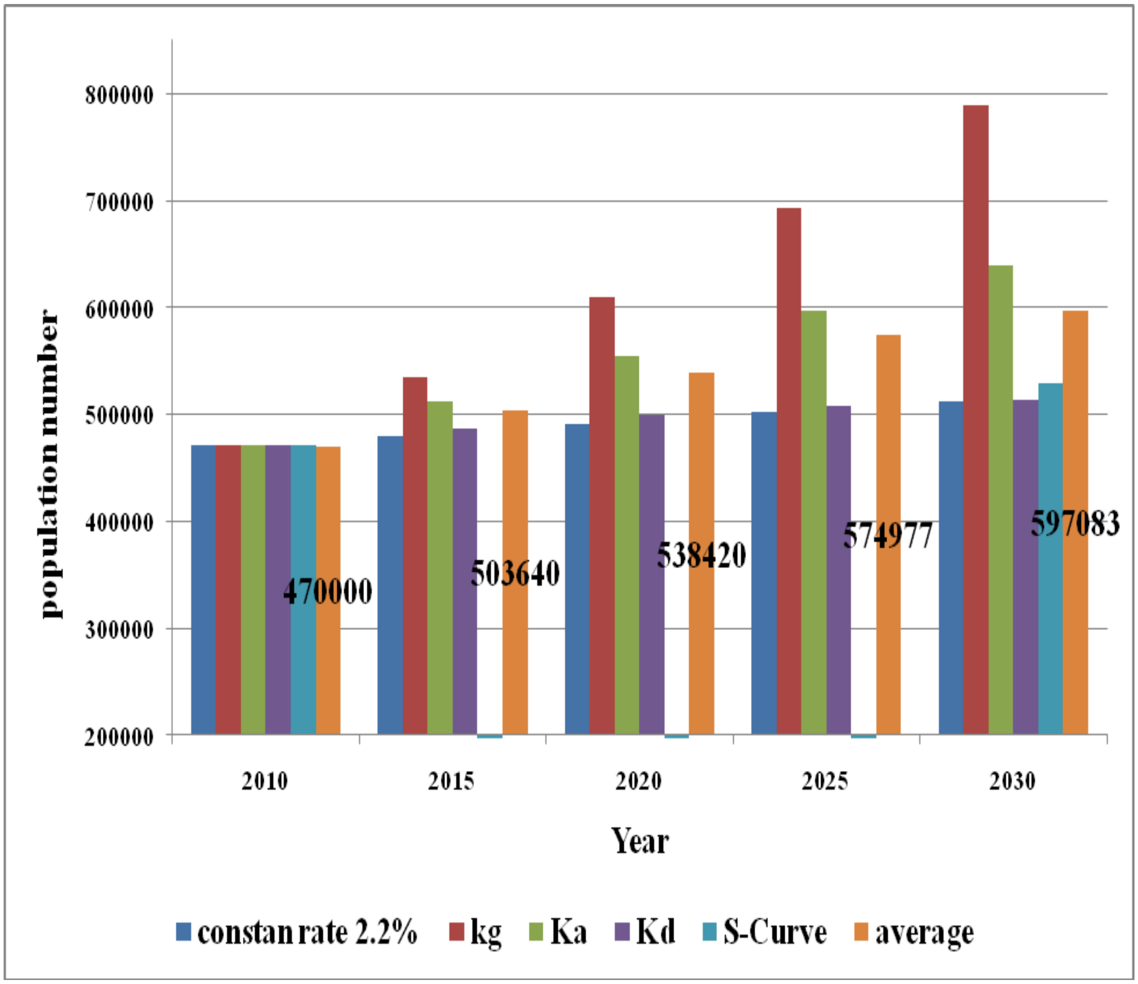

Figure (5): Zarqa Population Forcasting for the Years 2010 – 2030.

4.2 Solid Waste Generation

4.2.1 Commercial center

Represents the center of Zarqa City, it's the shopping destination; it contains the food, garments, building stores, workshops, restaurants, municipality offices and the bus stations. The commercial center is crowded almost all the time, since early morning till late evening. Furthermore, there are no spaces to use the steel 1.1 m^3 containers, so the shops dispose

their solid waste on the intermediate curb (see Figures 6.a and 6.b) where it's collected later by the municipality trucks.

Nowadays, Zarqa municipality started a program in some parts of the commercial center to collect the generated SW from the shops at a fixed time, twice a day. The people are required to dispose their waste in the morning between 9-11 am or in the evening between 6-8 pm.

In some places of the commercial center especially when residential apartments and shops are in the same building, the tenants dispose their waste directly infront of shops doors or in some cases they through it from the windows. This annoying behavior causes conflicts between the shops owners and the tenants. Furthermore, high solid waste generation rate and insufficient street sweeping causes a pile of waste to be accumulated in some parts of the center Figures (6.c, 6.d and 6.e).

Figure (6.a): Commercial SW on Intermediate Curb

Figure (6.b): Domestic SW on Intermediate Curb

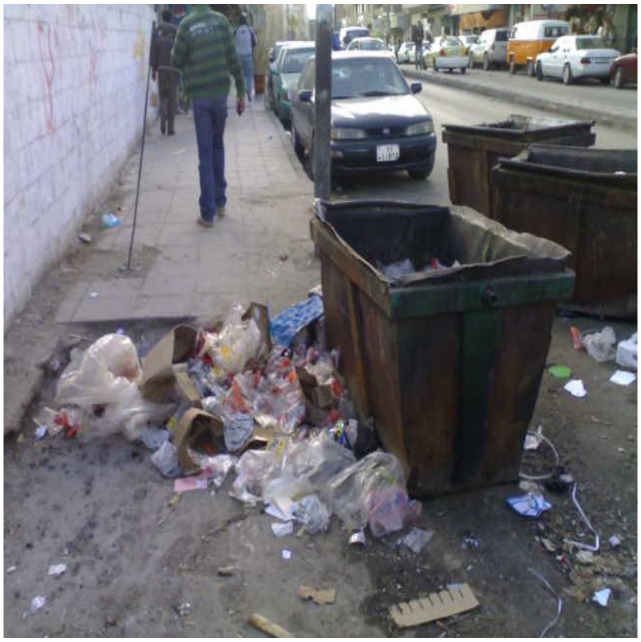

Figure (6.c): Accumulated SW due to Littering

Figure (6.d): Domestic SW in front of Shop Door

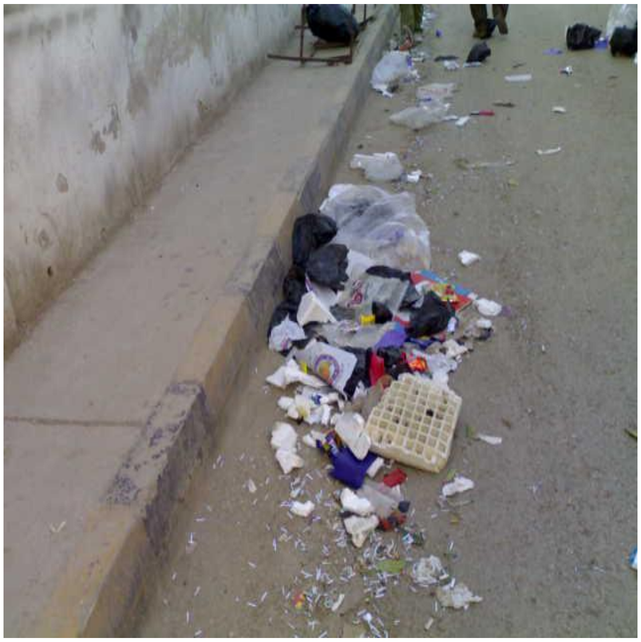

Figure (6.e) Accumulated SW due to Littering

4.2.2 Residential Area

Solid waste generated in the residential areas is disposed in public steel storage containers with a capacity of 1.1 m^3 placed in locations close to houses. In areas where dumpsters are not available, the citizens dispose their solid waste in plastic bags and place it at the curbside or near their houses. The accumulated waste on the side of streets is then picked up by the municipal workers and carried to the nearest steel container or disposed directly into the trash collection trucks. The population density within Zarqa city widely differs from one place to another, these differences are presented in Table (5) and Figures (8 and 9). The density of population would reach more than thirty thousand capita per km^2 in some places such as Al-Gowereieh and Prince Mohammad, or it drops down to less than two hundred capita per km^2 in other places such as Shomer or Al-Bustan neighbors. Moreover, as the density of population increases the roads and alleys that separate homes become narrower, which makes the solid waste collection task difficult and requires more labors and efforts. Furthermore, in some neighborhoods the steel containers are emptied three times a day due to the high solid waste generation rate and the lack of the solid waste containers. Figure (7) shows littered solid waste infront of some houses, this phenomenon may due to lack of steel containers or littering the solid waste by tenants.

Figure (7) Littered SW in Residential Area

Table (5): Population Distribution in Zarqa City.

Distinct No	**Population**	**Area Km^2**	**Average Population Density capita/km^2**
1	56,525	2.83	19,985
2	46,061	3.22	14,325
3	40,195	7.39	5,440
4	34,642	16.72	2,072
5	38,769	13.81	2,807
6	34,768	1.35	25,841
7	14,165	4.76	2,979
8	95,560	3.97	24,046
9	32,542	3.67	8,872
Wadi Alish , Al braim prince Mohammed City	57,536	0.18	9,232
Zarqa Camp	20,000	6.23	111,111
Total	470,763	64	NA
Average Density	NA	NA	7,355

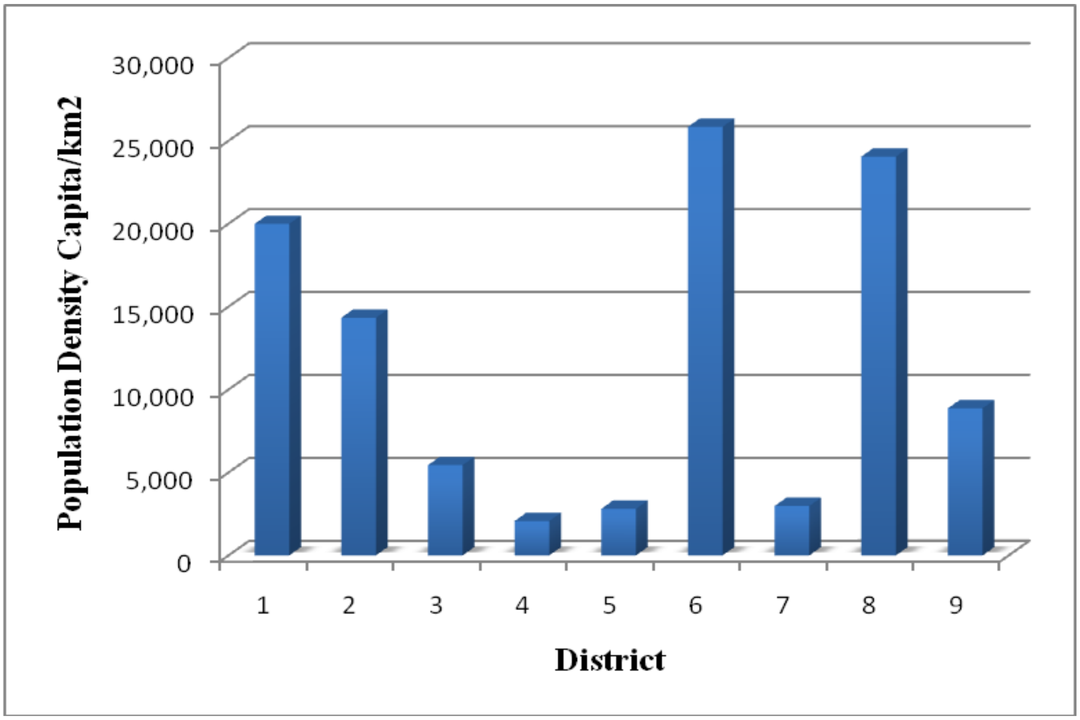

Figure (8): Population Density Distribution in Districts in Zarqa City.

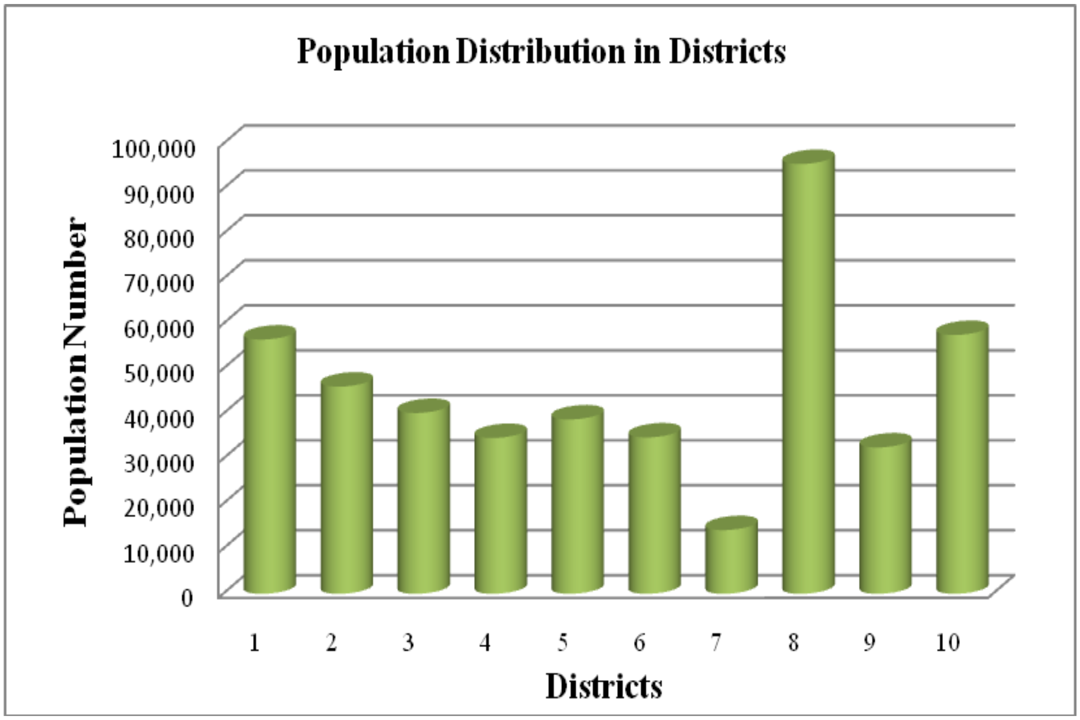

Figure (9): Population Distribution in Districts in Zarqa City.

4.2.3 Refugee Camp

According to the UNRWA office the population number of refugee camp, which was established in 1948 was 8,000, in an area of 0.18 square kilometers. Nowadays, the camp population is around twenty thousands (20,000) with a density about 111,111 capita/ km^2.

All environmental issues within the camp territory are carried out by UNRWA organization, so the solid waste collection is done by the organization employees, after that it is disposed on the border of the camp to be collected by the municipality vehicles.

No vehicle can enter the camp because of the narrow roads and very narrow and snaky alleys so the collection activities within the camp are done manually. The camp is divided into rows and each raw is responsible by one worker. In the morning the janitors sweep the streets and collect the solid waste that is disposed infront of homes doors, then dispose it in $8m^3$ waste container located on the camp border. The waste is then transferred to the transfer station.

The solid waste collection service is insufficient in the camp, as huge piles of waste are accumulated near the borders of the camp. Furthermore, open burning of the solid waste practiced, this increases the environmental pressure in the camp, annoy the neighboring tenants and causes air and visual pollution. Figures (10.a, 10.b and 10.c) show some of the examples of the problems related to the solid waste management in the camp.

Figure (10.a): Fire in the Solid Waste Container.

Figure (10.b): SW near the Railway.

Figure (10.c): Littered SW.

4.2.4 Workshops and Industrial Areas

As other cities in Jordan, workshops are distributed all over Zarqa city. In addition to the scattered maintenance shops and workshops in Zarqa city there are six complexes distributed in the city where different activities are practiced. These complexes are summarized in Table (6):

Table (6): Workshops Location and Activities in Zarqa City.

Complex Name (Location)	**Activities**
Wadi Alesh scrap	scraps and recycling
Opposite Sameh Mall, near Amman Zarqa high way	carpentry, blacksmith, and auto mechanic
Al Gundi workshop complex	Integrated complex
Awajan workshop complex	auto mechanic
Refinery complex	auto mechanic, blacksmith and carpentry
New Zarqa complex	carpentry, blacksmith and aluminum reformation

The industrial plants are scattered all over the city, and there is no special zone for the industry. Zarqa city contains wide range of industries like oil refinery, steel manufacturing tanning, paper milling, food and beverage, paints and chemicals. In general, there is no organized segregation for the solid waste generated by industries and workshops, except a small portion of recyclables that are sold to scrap yards. In addition there is mixing between domestic and industrial and hazardous waste, industrial and workshops solid wastes are stored in 1.1 m^3 or 8 m^3containers with domestic solid waste where it is transferred to the transfer station then to Al-Gabawi landfill.

4.2.5 Street Sweeping

Roadways are cleaned for aesthetic reasons and for health and environmental protection, (Jang, et al., 2009). To evaluate the adequacy of SW collection service a CEI is usually determined (Vesilind and Rimer, 1981). In Zarqa city it seems that the efficiency of sweeping is not enough, and this is clear from the low average value of CEI that the streets in Zarqa City achieved, see Table (7).

Table (7): CEI Survey Results.

Street Name	**Districts**	**CEI**
King Hussain	1	75
Prince Shaker	1	65
Amman	1	35
Almalab Al baladi	2	50
Al thawra	2	60
Ibn zaidon	3	45
Mohammad Gamgom	3	40
Khalid Bin Alwaled	4	50
Qurtoba Streert	4	60
Al karameh	5	50
Alamera	5	65
Alhashemi	6	60
Umaia	6	40
Badei Al-zaman	7	55
Ibn Batouta	7	40
Rabeia bin Alhareth	8	50
Abu baker	8	40
Yagoz	9	65
Tubas	9	70
Average CEI	53	

Normally, the street sweeping composition is soil, sediment, small piece of pavement, leaves and trash, these components are considered as carrying media for hazardous pollutants like Chromium, Lead, Nickel, Arsenic and Barium. The relevant composition for street sweeping and its pollutants depend on sweep type, traffic load, road type, location and weather (Jang, et al. 2009). In Zarqa city street sweeping contains high fraction of trash due to littering of solid waste, installation of solid waste bins in the city center and bus station will affect the amount of littered solid waste. The number of required bins in the city center is calculated based on the street length in Table (8), and bins operation and maintenance costs are summarized in Table (9). The bins will be fixed every 50m on each side of the road.

Table (8): Main Roads in the City Center and its Length.

Street Name	**Length (m)**	**Street Name**	**Length (m)**
Amman	925	Algaish*	815
Sheihk Abd Alah	350	Baghdad	422
King Faisal	900	Prince Shaker	595
Sulatn Abd hamid	253	Abd Moneam reyad	579
King Abdualah	918	Bab Alwad	577
Alsaadeh	911	Hag Murad	565
Shamel	888	Tash	555
Prince Nayef	923		
Qasem Bolad	947		

*Algaish street is longer, only 815 m long from the street is covered.

Table (9): Bins Installation and Operation Cost.

Cost of manufacturing and installation of one metal bin*	20 JD
Length of main streets in the city center	10308 m
Total number of Bins to be fixed at main streets	420 bins**
Number of people living in Zarqa city	470,760
Number of people per bin	1,121
Number of bins in bus station	40
Total number of bins in Zarqa city	460
Total cost of bins to be installed in Zarqa city	9,600
Time needed to empty one bin	0.17 hr
Number of times per year every bin will be emptied	365 times
Annual time required to empty one bin	60.8 hr
Annual working time for one worker (300 days×7 hr/day)	2,100 hr
Number of bins emptied per worker	35
Number of workers needed to empty all bins (460×0.17×365/2100)	13
Annual salary for 1 worker (181 JD/Month×12 Months)	2,172 JD
Annual labor cost for emptying bins	28,943 JD
% of bins replaced or damaged every Year	20%***
Cost of replacement	1,920 JD
Total cost of bins installation and operation per year	**40,463 JD**

*Municipality Workshop.

** The Calculated Number of bins is 413, but to ease the calculation 420 bins used.

*** Jordanian Income Tax Law No (57) 1985, Consumption Rate Instruction No (5) for the Year 2002.

4.3 Solid Waste Collection and Transportation

Optimization the solid waste collection services can reduce the management cost and reduce the health and environment impacts. Transportation of municipal solid waste is the responsibility of Zarqa municipality. The collection vehicles may be 5 or 10 tons compactors or trucks where it is directly loaded by worker. Zarqa municipality also deals with all solid waste that are generated from industries, institutions and workshops located within its territory.

The collected waste is transported to a transfer station that is located 12km from the commercial center of the city toward the south west. Then the solid waste is transferred to Al-Gabawi landfill which is located in Amman 36 km from the transfer station (Zarqa municipality, 2011). SW collection service is offered against fixed fee based on the Regulation of Waste Prevention and Fees No (89) for the year of 1998 issued by the Ministry of Municipal Affairs. The domestic fee charge is (24 JD/year). The fees are collected as monthly supplement to the electricity bills that are collected by the National Electricity Company which deducts 10% of the total collected amount as logistic services (Sweep net, 2010).

On the other hand, for commercial sector there are no fixed fees. The fees are calculated based on the municipality decision No (5/71) dated 8/12/2010 that classifies the commercial activities depending on its nature and the amount of the solid waste that is expected to be generated from these activities. The fees are paid annually with the registration renovation.

Solid waste fees are declared on the registration certificate. However, most of the time the municipality charges the shops extra waste fee. The shops owners think that the extra waste fee is the only fee that they pay for solid waste services. While in fact they pay almost a fix charge of 24 JD for solid waste services, and in most cases an extra waste fee depending on the shop nature and activities. For example, in one of the survey, a shop owner indicated that he only paid 15 JD for solid waste services, while in fact he paid 15 JD for extra waste fee and 24 JD for solid waste services; a total of 39 JD.

The misunderstanding of the fees paid for solid waste, had caused the shop owners to underestimate the actual fees paid for solid waste, and thus not paying enough attention on

For organizational purposes Zarqa City is divided into 6 districts, while for solid waste management services it is divided into 9 districts; in some places one or more neighborhoods are common between two or three districts. To manage and evaluate the workers activities, every district has its own team, collection vehicles and tools. The team consists of one manager, supervisors, labor inspector (foreman) and collection and sweeping workers. In addition, there is an environmental manager for the municipality. The district manager is an engineer, while supervisors have higher education certificate.

According to the council head of the municipality, the number of registered staff for solid waste management in the municipality is between 1300-1400 persons, excluding the financial and legal staffs. However, the actual number of workers in SW management is about 60% of this number; the remaining workers serve in other department in the municipality or do not participate in the SW activities.

Furthermore, there are about 1190 -1250 SW containers with a capacity of 1.1m^3 and 70 SW containers with capacity of 8 m^3 distributed in the city. Tables (10 and 11) summarize the distribution of the solid waste management workers, collection vehicles and solid waste containers in Zarqa city.

Table (10): Summary of the Teams and Vehicles Working in SW Collection Process.

District No	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
No of Manager	1	1	1	1	1	1	1	1	1	9
No of Supervisors	2	2	1	1	3	2	2	2	2	16
No of Labor Inspectors	12	7	8	18	10	11	11	13	7	75
No of Drivers	6	5	5	3	8	6	4	6	4	47
No of Workers	117	52	49	42	85	47	54	51	39	482
No of 5 tons compactor*	4	1	1	2	3	1	2	3	2	19
No of 10 tons compactor*	-	1	2	-	1	2	-	-	-	6
No of Truck 2.5 tons	1	2	1	-	3	3	1	2	2	15
No of Shifts	2	2	2	2	2	3	2	3	2	20
SW ton/day**	48	34	26	25	34	40	30	40	25	302

(Zarqa Municipality, 2011)

*there are extra two 10 tons compactors and three 5 tons compactors as stand by.

**the solid waste estimations are based on the information provided by districts managers, with the utilization factor between 60-70%.

Table (11): Number of Vehicles and Containers.

Vehicles Type	**Numbers**	**Notes**
Loader	1	Used to load the demolition waste and for other works
Bob cat	5	Used to collect the
Mercedes Truck	6	It is used to collect the demolition waste with capacity of 12 m^3
No of 1.1 m^3containers	1190 -1250	The number of containers are not fixed because of regular maintenance
No of 8 m^3containers	70-80	The number of containers are not fixed because of regular maintenance

(Zarqa Municipality, 2011)

Figures (11.a and 11.b) show the status of solid waste containers. According to the municipality workers, 55-60% of the total number of containers is partially or totally damaged. This causes delaying in collection time due to the extra effort required to move the damaged containers and due to solid waste spillage, which means the need to collect the scattered solid waste. Moreover, the workers can't collect all the spilled solid waste, which causes visual pollution near the damaged containers. This is shown in Figure (11.c) where the workers are trying to carry the damaged container after the spillage of its content. Furthermore, the citizen sometimes disposes their solid waste beside the waste containers to form piles of solid waste, Figure (11.d). Thing increases the pressure on the waste collection team, affects the quality of the municipality services and increases the degree of citizen's unsatisfaction.

Many containers require maintenance, some of them are damaged and not suitable for solid waste discharge, and this requires extra time to discharge the solid waste. Rounds with collection vehicles were done to evaluate and measure the extra time required to empty the solid waste containers, the rounds result are shown in Table (12).

The container emptying time depends on the status of the container, if the container is in good condition it requires in average 40-65 seconds to be emptied depending on its load quantity and quality, location, topography, personnel factors. On the other hand, if the container is in bad condition, it requires on average 95-120 seconds to be emptied depending on the above mentioned factors plus the degree of container damage. That means an extra time between 30-80seconds is required to empty each damaged container, which results an extra total time between 12 - 33 hr/day to empty all the damaged containers in the city, these results are summarized in Table (13) and the sample of calculations after it.

Figure (11.a): Bad Condition of SW Container.

Figure (11.b): Bad Condition of SW Container.

Figure (11.c): Waste Spillage During Collection.

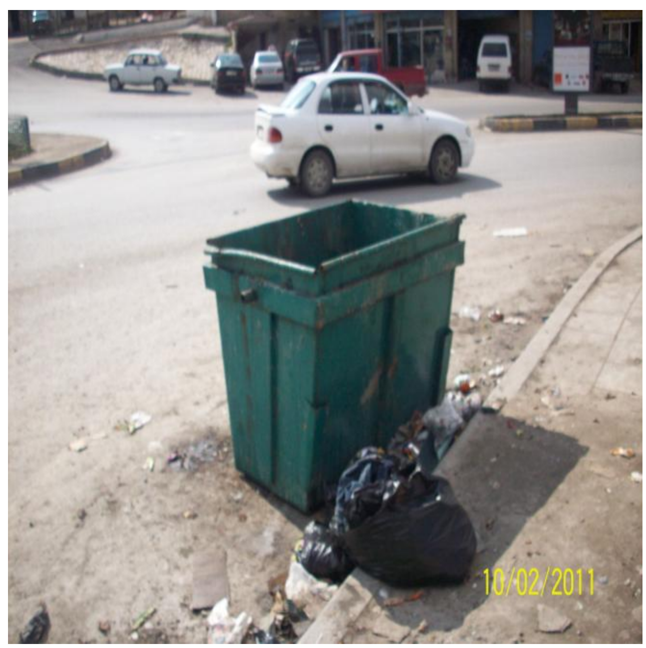

Figure (11.d): Piles of SW beside the Container.

Table (12): Collection Times for Solid Waste Containers.

Date of Trip	Trip No	District No	No of Collected Containers	Container Collection Time (sec)	Pile Collecting Time (sec)	Total collection Time (sec)	Collected Container Status
8/1/2011	1	2	2	182	223	405	bad
8/1/2011	1	2	-	-	48	48	
8/1/2011	1	2	1	33	-	33	good
8/1/2011	1	2	2	186	30	216	bad
8/1/2011	1	2	2	120	320	440	good
8/1/2011	1	2	2	198	57	255	moderate
8/1/2011	1	2	5	271	-	270	moderate
8/1/2011	1	2	1	95	47	142	bad
8/1/2011	1	2	1	114	-	114	bad
8/1/2011	1	2	1	108	67	175	bad
8/1/2011	1	2	1	32	-	32	good
8/1/2011	1	2	1	39	-	39	good
8/1/2011	1	2	1	77	-	77	good
19/1/2011	2	5	1	100	75	175	bad
19/1/2011	2	5	1	53	-	53	good
19/1/2011	2	5	2	146	89	235	moderate
19/1/2011	2	5	-	-	32	32	-
19/1/2011	2	5	2	178	48	226	bad
19/1/2011	2	5	3	349	88	437	bad
19/1/2011	2	5	1	80	-	80	bad
19/1/2011	2	5	2	103	-	103	good
7/2/2011	3	1	3	161	55	216	good
7/2/2011	3	1	1	100	-	100	bad
7/2/2011	3	1	1	107	73	180	bad
7/2/2011	3	1	1	94	68	162	bad
7/2/2011	3	1	1	37	14	51	good
7/2/2011	3	1	2	218	102	320	bad
7/2/2011	3	1	2	96	41	137	good
3/3/2011	4	4	2	217	-	217	bad
3/3/2011	4	4	2	149	-	149	moderate
3/3/2011	4	4	2	254	78	332	bad
3/3/2011	4	4	2	162	93	255	moderate
3/3/2011	4	4	2	148	115	263	moderate
3/3/2011	4	4	1	103	-	103	bad
3/3/2011	4	4	1	100	45	145	bad
3/3/2011	4	4	2	171	-	171	moderate
3/3/2011	4	4	1	99	116	215	bad
3/3/2011	4	4	1	63	38	101	good

Table (13): Summary of Lost Times during the Collection of Solid Waste.

Extra time required to empty one container	**Total extra time for 1190 Containers (hr/day)**	**Total extra time for 1250 Containers (hr/day)**
30 sec	12 hr/day	13 hr/day
40 sec	16	17
60 sec	24	25
80 sec	32	33
Minimum Cost	11,388 JD/year	
Maximum Cost	31,317 JD/year	

The extra time required to empty the containers is calculated based on the following assumption.

1- Every container is emptied twice a day.

2- The damaged container is 60% from the total number of containers.

3- The average monthly salary for vehicle driver is 250 JD and the average monthly salary for two workers with the collection vehicles is 400 JD/month (200 JD/each) so the average hourly salary for one vehicle (driver and two workers) is 2.6 JD/hr

- **Sample of calculation:**

Minimum Time required for the containers discharge = 1190 x 0.6 x 2 x 40 sec/ (60 x 60) = 15.8 ≈16 hrs/day

Minimum cost = 12 hr/day x 2.6 JD/day = 31.2 JD /day x 365 days/year = 11,388 JD/year

Maximum cost = 33 hr/day x 2.6 JD/day = 85.8 JD /day x 365 days/year = 31,317 JD/year

On the other hand, if every container is discharged twice a day, and if there is pile of waste near only 40% of the all containers, at least one thousands piles will need to be collected per day. If every pile requires only one minute to be collected, then the minimum annual cost for collection of one thousands piles of solid waste is

[(1000 pile/day x 1 min) / 60 min/hr] 2.6 JD/hr x 365day/year = 15,816 JD/year

The piles annual collection cost may reach 79,083 JD/year (in case of 1000 piles to be collected per day with collection time equals five munities per pile).

In addition, the cost of extra fuel during the engine idle time (waiting time to collect the solid waste) can be estimated using the United State Department of Energy (US DOE) model, that assumes the fuel consumption ranges from 0.6 gallons per hours for a truck idling at 800 round per minutes (rpm) with no accessories to 2.25 gallons per hours for a truck idling at 1200 rpm (Brodrick et al., 2002). So if the municipality collection vehicles require an extra time 12 hours/day only due to the damaged waste container and 17 hours/day to collect the waste piles, this means the municipality vehicles work 29 hours/day more. And this will increase the collection cost due to extra fuel consumption, which is calculated as the following:

29 hr/day x 0.6 gallon /hr x 3.785 litter / gallon x 0.52 JD/litter x 365 day/year = 12,500 JD/year

4.4 Transfer Station

4.4.1 SW Transferring

Once a collection vehicle has full load, it hauls the solid waste directly to the transfer station, located to the western south of the city of Zarqa, at 12 km from the commercial (city) center. The transfer station was established in 2006, the location was determined with cooperation with the Ministry of Environment and other related governmental authorities, the transfer station replaced the old landfill near Al-Sukhneh (Zarqa Municipality, 2011).

The total area of the transfer station is 12,000 m^2, while the used area is only 7,000 m^2. The official working hours for the transfer station are from 7 am – 11 pm with two working shift. In some days the transfer station receives the solid waste until 3:00 am.

The work in the transfer station is divided into collecting recyclable materials and transferring the solid waste to Al-Gabawi landfill. Solid waste is transferred by both municipality and private contractor vehicles, Tables (14 and 15) summarize workers and machines for both the municipality and the private contractor in the transfer station. the Annual Tender is issued for solid waste transferring process, according to the department of finance in the municipality, the current price for solid waste transferring to Al-Gabawi is (3.11 JD/ton of waste). In the last year (2010) the price was 3.69 JD per ton of transferred waste, while in 2009 the price was 3.75 JD per ton.

On the other hand, the municipality makes income by issuing tender to benefit from recyclable materials in the transfer station, where it allows only for one contractor to work and recover the recyclable materials; this is done by tendering system. The awarded tender for transfer station investment for this year was 15,500 JD (Zarqa Municipality, 2011).

Table (14): Summary of the Total Municipality Workers and Machines at Transfer Station.

Position Title	**Morning shift Person No**	**Night Shift Person No**	**Machines**	**Number of Machines**
Site Manager	1	-	Mercedes Truck Model 2004	1
Supervisor	1	1	Mercedes Truck Model 2008	1
Labor Inspector	1	1	Mercedes Truck Model 2008	1
Driver	3	2	Trailer Body	4
Workers	3	2		
Guard	7	7	Compactor	2

(Zarqa Municipality, 2011)

Table (15): Private Contractor Workers and Machines at Transfer Station.

SW Transferring Contractors	**No**	**Notes**
Manager	1	
Labor Inspector	1	
Loader Driver	1	
Vehicles Drivers	8	
Worker	1	The worker wraps the Trucks
Mercedes Truck	8	12 m^3 capacity
Loader	1	
SW Separation Contractor		
Workers	15-20	work on the daily base and get 15 JD/day
Pick Up	2	

(Zarqa Municipality, 2011)

Usually the work in the transfer station is divided between three subcontractors, one for plastic, and two others for metals and paper and cardboard (Zarqa municipality, 2011). The separation process is done manually, after discharging the content of collection vehicles; the workers recover the recyclable materials as much as they can. According to the transfer station manager, the estimated amounts of recycled materials are 8 tons daily, 4 tons for paper and cardboard and the remaining amounts are metals and plastics. The materials recovery is done during the day only to benefit from the daylight.

In the transfer station the SW is compacted using the compactor which is show in Figures (12.a and 12.b) and sent to Al-Gabawi landfill which is located 37km from the transfer station in Amman city. Comparison between the amounts of solid waste that are transferred to Al-Gabawi landfill for Amman, Zarqa and Rusaifeh cities for the year of 2010 is shown in Table (16). The total amount of SW that transferred to Al-Gabawi landfill from Zarqa city in 2010 was 106,203 tons with daily average about 291 tons/day.

While for Amman city it was 730,826 tons with daily average about 2,002 tons/day, and for Rusaifeh the total transferred waste was 61,705 tons with daily average of 169 tons/day. Al-Gabawi landfill has a balance scale to weight all solid waste vehicles. The solid waste disposal cost in Al Gabawi landfill is around 3 JD per ton. According to Al-Gabawi manager Zarqa municipality does not pay any fees to dispose its solid waste in the landfill. The SW is transported by municipality and private contractor vehicles.

Figure (12.a): Compacting SW at the Station.

Figure (12.b): SW Transfer at the Station.

Table (16): Total Amount of SW Received in Al-Gabawi Landfill in 2010.

Month	Amman ton / Month	Zarqa ton / Month	Rusaifeh ton / Month
January	60,101	6,475	5,264
February	52,710	4,459	4,049
March	61,393	7,088	5,021
April	58,023	5,230	4,502
May	63,364	7,708	6,106
June	66,047	8,789	5,352
July	68,089	11,380	5,554
August	65,944	16,663	5,780
September	60,051	12,747	5,565
October	58,780	8,068	4,419
November	56,740	7,870	5,199
December	59,584	9,726	4,894
Total	730,826	106,203	61,705
Monthly Average	60,902	8,850	5,142
Daily Average	2,002 tons/day	291 tons/day	169 tons/day

(Greater Amman Municipality, 2010)

4.4.2 Solid Waste Composition

Samples from the solid waste received by the transfer station were analyzed to measure the waste components, examples of the separated waste components are shown in Table (17). The total number of collected samples were fourteen, the sampling continue between February to May of the year of 2011, it covers all the week days except the Fridays, where solid waste is not transferred to Al-Gabawi landfill on Fridays. The received solid waste is accumulated in the transfer station, then some recyclables materials are collected, see Figures (14a, 14.b and 14.c). The results show that the average fractions by weight for the main components are 48.9%, 13.3%, 15.2%, 5.8% for organic, paper and cardboard, plastic and textile, respectively, see Table (18). The other fractions are metals, rubber and leather, glass and miscellaneous distributed as the following, 3.1% for metals, 3.8% for glass, 2.6% for leather and rubber and 7.3% for miscellaneous Figure (13).

Table (17): Materials Type of Solid Waste in the Transfer Station.

Organics	Vegetable, Fruit, rice, meat, bread, all kind off foods
Paper & Cardboard	magazine, newspaper, books, notebooks, carton box
Plastics	bottles, bags, dishes, packaging waste, toys
Textile	fabric sponge, nappies, sponge
Rubber & Leather	shoes, rubber band
Glass	all kind of bottles, bottles of toilette water
Metals	tin, can, spray cans, steel accessories
Miscellaneous	wood, sticks, dead animals, drugs, diapers, batteries, damaged electronics

Table (18): Composition of Solid Waste %by Weight at the Transfer Station.

Day	Date	Organic % weight	Paper & Cardboard % weight	Plastic % weight	Textile % weight	Rubber & Leather % weight	Metal % weight	Glass % weight	Miscellaneous % weight
Sat	12/2/2011	57.8	13.8	13.9	5.6	2.1	1.5	1.9	5.4
Sun	13/2/2011	49.6	13.9	14.4	7.1	2.2	3.9	4.2	6.6
Sun	13/2/2011	52.0	12.5	15.3	5.0	3.5	4.0	4.0	5.8
Mon	14/2/2011	47.3	13.4	16.6	4.9	2.0	4.3	5.3	7.1
Mon	14/2/2011	48.1	15.0	15.3	5.6	3.5	3.2	3.6	6.8
Tues	15/2/2011	49.1	13.1	17.3	7.3	1.5	4.3	4.3	6.1
Thurs	17/2/2011	49.7	15.8	13.4	6.9	3.1	2.3	4.4	6.6
Thurs	17/2/2011	48.0	12.5	16.3	6.4	3.3	5.1	5.7	3.8
Sat	26/2/2011	50.2	12.9	15.2	7.1	6.1	2.7	4.0	7.4
Tues	1/3/2011	53.6	12.0	18.5	4.4	0.3	1.6	2.8	8.7
Wend	2/3/2011	48.6	13.8	15.2	6.4	2.5	3.4	4.1	5.9
Wend	9/3/2011	48.2	15.3	15.0	5.4	2.5	3.1	3.4	8.0
Wend	13/4/2011	37.8	9.7	11.6	6.0	1.1	2.5	3.4	9.2
Thurs	5/5/2011	44.6	12.1	14.6	3.1	2.2	2.2	1.5	11.3
Average		**48.9**	**13.3**	**15.2**	**5.8**	**2.6**	**3.1**	**3.8**	**7.3**

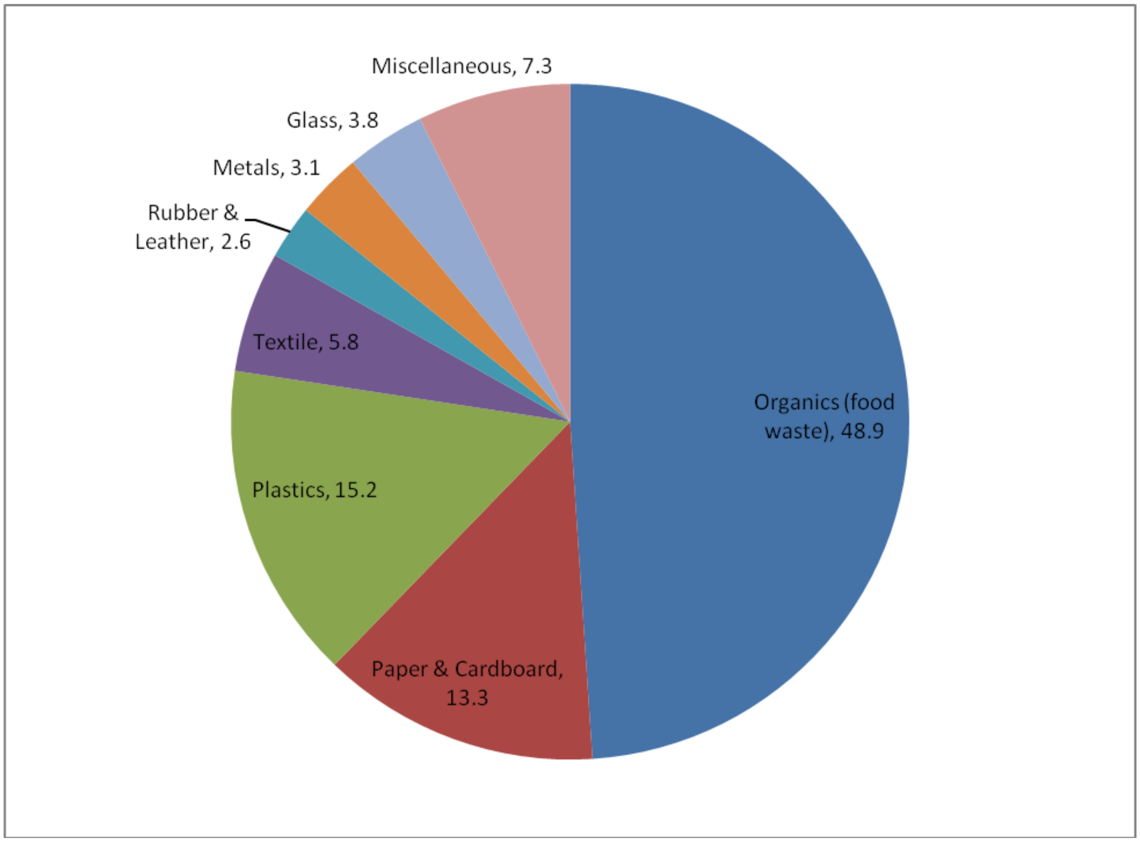

Figure (13): Average Distribution of SW Composition at the Transfer Station.

Making a comparison between the solid waste fractions that are received at Zarqa transfer station and the ones received in al-Akeder, Al-Husseniat and Al-Humra landfills are summarized in Table (19). The component O.M refers to organic matters which are food waste and food residues, and the term H.M refers to hazardous materials like batteries, solvent cans, while the term others in the table refers to wood, shoes, CDs, mother boards and unknowns.

Table (19): Comparison of Solid Waste Composition.

Landfill	SW ton/day	O.M	Plastic	Cardboard & Paper	Metal	Glass	Textile	leather & Rubber	Diapers	H. M*	Others
Akeder	700	40.6	18.3	10.2	2.1	2.1	8.9	0.9	15.6	0.3	1
Husseniat	100	35.5	16.8	11.8	3.6	2.9	8.1	1.7	17	0	2.6
Humra	200	40.3	16.3	14.7	5.8	2.9	8.5	2	8.7	0	0.8
Zarqa T.S	291	48.9	15.2	13.3	3.1	3.8	5.8	2.6	-	-	7.3

(Ministry of Environment and RSS Report, 2009)

*H.M: Hazardous Materials

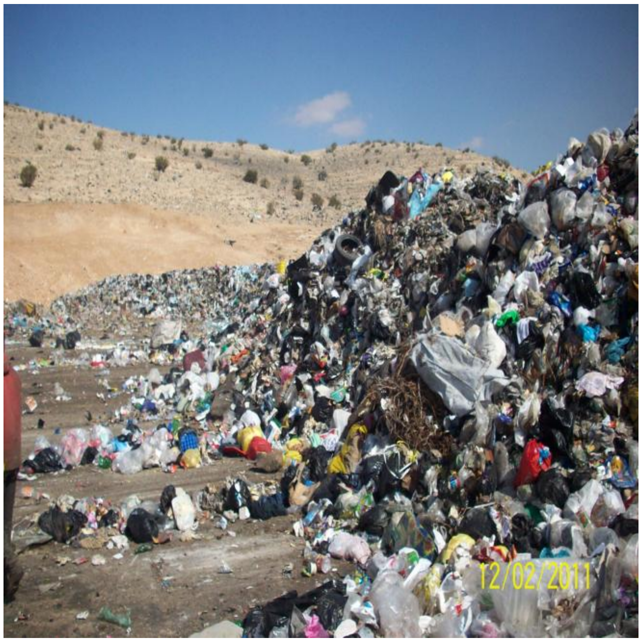

Figure (14.a) SW at transfer Station on Saturday. Figure (14.b) SW at Normal Working Day.

Figure (14.c) Separated Cardboard at Transfer Station.

4.4.3 Solid Waste Density and Moisture Content

The density of the solid waste was determined by weighing the specific volume of waste ($0.084\ m^3$). The average weight of five uncompacted samples of solid waste was 13.89 kg so the average density is 165 kg/m^3.

To determine the moisture content of the solid waste, the drying method was used. Three samples of the solid waste were prepared. The samples were weighed and subjected for drying in an oven at 105°C, after which they were weighed again. The actual moisture content percentage was calculated as the difference in weight before and after drying divided by the weight before drying, so the actual average moisture content percentage was 45%.

4.4.4 Heat Content

Calculated based on the determination of the composition of the SW that is transported to the transfer station, and then validated by proper formulas. The procedure is simple; first the solid waste composition is determined. Then based on the typical (theoretical) moisture contents available in the text book (Tchobanoglous et al. 1993), the dry weight is determined (Tchobanoglous et al. 1993). After that, the atomic percentage is determined based on the typical atomic value in each waste component. At the end, the formula and the heat content is calculated. Summery of these results are shown in Tables (20, 21 and 22)

Table (20): Solid Waste Composition and its Atomic Values Representation.

Waste Composition	SW Distribution	Typical %Moisture	Dry Weight	Composition					
				C	H	O	N	S	Ash
Organics	48.9	70	14.67	7.0	0.9	5.5	0.4	0.1	0.7
Paper and Cardboard	13.3	34	8.78	3.8	0.5	3.9	0.0	0.0	0.5
Plastics	15.2	2	14.90	8.9	1.1	3.4	-	-	1.5
Textile	5.8	10	5.22	2.9	0.3	1.6	0.2	0.0	0.1
Rubber and Leather	2.6	6	2.44	1.7	0.2	0.1	0.1	0.0	0.2
Metals	3.1	2	3.04	0.1	0.0	0.1	0.0	0.0	2.7
Glass	3.8	2	3.72	0.0	0.0	0.0	0.0	0.0	3.7
Miscellaneous	7.3	-	-	-	-	-	-	-	-
Total weight of Compostable Fractions	**85.8**		**46.01**	**24.4**	**3.1**	**14.5**	**0.8**	**0.1**	**3.1**

On behalf of the values in the above table, the moisture content can be determined as the difference between the total of organic fraction of SW and the total Dray weight of the organic fraction

Theoretical moisture content = 85.8 - 46.01 = 39.80% ≈ 40%

Note: the calculated theoretical moisture content is less than the measured one, because the measured moisture content considers all the water in the solid waste components plus the traces of water on the glass and metal surfaces.

The heat content is calculated depending on the compostable fractions of solid waste which are (organics, paper and cardboard, plastic, textile, rubber and leather). The atomic compositions are calculated based on the typical values recorded in Tchobanoglous et al. (1993) and the average SW composition that is determined at the transfer station in Zarqa city.

Table (21): Atomic Weight Composition and Mole Fraction of Solid Waste Components.

Components	Weight		Atomic Weight	No of Moles		Mole fraction	
	Without H_2O	With H_2O		Without H_2O	With H_2O	Without H_2O	With H_2O
Carbon	24.355	24.355	12.100	2.013	2.013	670.936	670.936
Hydrogen	3.103	7.519	1.010	3.072	7.445	1023.945	2481.671
Oxygen	14.550	49.885	16.000	0.909	3.118	303.121	1039.273
Nitrogen	0.795	0.795	14.010	0.057	0.057	18.903	18.903
Sulfur	0.089	0.089	32.070	0.003	0.003	1.000	1.000
Ash	3.081	3.081	-	-	-	-	-

The mole fractions are calculated by dividing all the elements moles by number of sulfur mole (0.003). By other words, we normalize the mole fraction based on the sulfur content.

As the result of calculated Mole Fraction of SW with or without water, the formula of the SW can be determined as the following:

Suggested formula of SW without water: $C_{670.9}H_{1023.9}O_{303.1}N_{18.9}S$

Suggested formula of SW with water: $C_{670.9}H_{2481.7}O_{1039.3}N_{18.9}S$

Table (22): The Percentage Contribution of Element in SW Composition.

Component	**No of Atom per Mole**	**Atomic Weight**	**Weight Contribution of Element**	**% Contribution of Element**
Carbon	670.9	12.1	8,118.3	29.5
Hydrogen	2,481.7	1.0	2,506.5	9.1
Oxygen	1,039.3	16.0	16,628.4	60.4
Nitrogen	18.9	14.0	264.8	1.0
Sulfur	1.0	32.1	32.1	0.1
		Sum	**27,550.2**	

Weight Contribution of Element = No. of Moles of Atoms x Atomic Weight

% Contribution of Element = Weight Contribution of Element / Sum of Weight

Example of Calculation: for Carbon Atom:

Weight Contribution = 670.9 x 12.1 = 8,118.3

% Contribution = 8,118.3 / 27,550.2 = 29.5%

Using the date in Table (21), the heat content can be determined using the formulas mentioned in Table (1) as the following.

The highest heat value (HHV) of energy content for the combustible fraction of solid waste depending on ultimate analysis is:

(HHV)= 145C + 610(H- O/8) + 40S + 10N = **5,235 Btu/lb = 2,905 kcal/kg**

Or

Heat content for the combustible fraction of solid waste depending on physical composition using Conventional model is:

H_n= 88.2R+40.5 (G+P) - 6W **= 2,310 kcal/kg = (4,157 Btu/lb)**

Or

Heat content for the combustible fraction of solid waste depending on ultimate analysis using Dulong equation is:

H_n = 81C + 34.2[H - O/8] +22.5 S- 6[9H + W] = **2,121 kcal/kg = (3,817 Btu/lb)**

Or

Heat content using Khan and Abu Ghrarah formula

H = 23{F + 3.6 (PA)} + 160 (PL) = **4,658 Btu/lb = 2,585 kcal/kg**

4.4.5 Resource Recovery

The materials recovery in Jordan and more specifically in Zarqa city is implemented on two levels:

1. Informal level by scavengers.
2. Formal level regulated by municipalities or NGOs, this is done at the landfills, transfer station or through cleaning campaigns.

Scavengers play a role in reducing the volume of disposed solid waste at the generation points. It is common to see individuals scavenging through the waste mostly in search for cardboard, tins and plastic. Usually, after collection of the valuable recyclable materials it is passed to factories or scrap yards. This is done directly by the scavengers or through dealers. The scavengers usually perform their job in a very primitive way and without any protective measures. This leads to high risk of infection and disease transmission.

Zarqa municipality did a pilot project for MRF. The facility was constructed as part of a comprehensive project for solid waste management improvement in the city, which was supported jointly by the UNDP. According to the initial estimations the annual expected revenue was around 177,000 JD. Unfortunately, the project and the facility were stopped in 2002.

At the time being, according to the separation contractors who work at the transfer station the materials that are recovered from the SW are 4-5 tons per day of paper and cardboard about 1-2 tons per day of plastic and about 1-2 tons per day of metals.

4.5 Service Performance Indicators

After collecting and determining the service indicators for Zarqa city a comparison between these indicators for Amman, Irbid and Zarqa was done in Table (23). The indicators values for Amman and Irbid were obtained from Sweep net (2010) country report.

Table (23): Solid Waste Service Indicators in Jordanian Cities.

Indicator	**Unit**	**City**		
		Amman	**Irbid**	**Zarqa**
Community Effect Index	-	82	63	53
Number of Service Regions	No	20	12	9
Population Served	Person	1,800,000	371,000	470,763
Population Served per Worker	Persons	630	742	736
Population Served per Vehicle	Persons	11,320	14,840	9,607
Average Daily Number of Containers Served per Collection Vehicle	No.	37.7	42.2	35.3
Ratio of Workers to Labor Inspectors		8.6	12.5	6.6

- Supervisor Controls the Work of the Drivers, Labors and Inspectors.

4.6 Questioner Results

Questioners were developed to complete the solid waste assessment in Zarqa. The questioner results indicated that 70% of the surveyed families dispose their waste once a day, 65% of them dispose it between 6 am – 10 am, while other families dispose it at different times during the day. On the other hand, all the families that dispose their waste two or three times a day dispose it all the time during the day.

About 78% from the surveyed people are willing to dispose their waste at fixed time, but they did not agree on a specific time, 31% of them preferred 6-8 am while 49% of them preferred 8-10 am, and the remaining preferred different times. These differences may be due to different time when people leave their home. Moreover, 20% of the people do not dispose their waste in the waste container, some of them because they don't have waste container near their homes, while others they don't care about it.

User Satisfaction Index (USI) was used to measure the degree of citizen's satisfaction toward the solid waste collection services (Vesilind and Rimer, 1981). By asking the people about their assessment for the offered solid waste services, and then rating their answers, see Table (24) for domestic and Table (25) for commercial activities.

Table (24): USI of Solid Waste Service for Families.

Choices	**Excellent**	**Good**	**Average**	**Accepted**	**Bad**
Rate	100	85	65	50	35
Frequency	8	70	52	26	25
(Rate x Frequency)	800	5,950	3,380	1,300	875
Sum	12,305				

$$USI = \sum_{i=1}^{N} \frac{R_i}{N} \tag{4.5}$$

Where:

R: sum of rate

N: Number of samples

USI = 12,305/181 = 68% which means municipality services is rated as average.

25% of the commercial activities in Zarqa dispose their waste in the morning when they open between 8 am-11 am. While 46% of them dispose it at evening between 6 pm – 8 pm Most of the shops (47%) dispose their waste in bags, where 27% of them use waste containers to dispose the waste and 13% of the shops use carton. 86% of the surveyed shops agree to dispose their waste at fixed time. 83% of the shops prefer to dispose their waste in the morning, while the restaurants don't prefer to accumulate any waste but to dispose it frequently as they have it. At the time being, about 63% of the surveyed shops are paying 24 JD as waste fee and 15 JD as extra waste fee. The remaining activities pay different fee, this fee varies from 10 JD for watch shops to 3,000 JD for Malls.

Table (25): USI of Solid Waste Service for Shops and Commercial Activities.

Choices	**Excellent**	**Good**	**Average**	**Accepted**	**Bad**
Rate	100	85	65	50	35
Frequency	10	27	6	33	6
(Rate x Frequency)	1,000	2,295	390	1,650	210
Sum	5,545				

USI = 5,545/82 = 68.8% which means municipality services is rated as average.

5 DISCUSION

In this chapter all existing issues related to the findings and municipal solid waste management will be analyzed and discussed. Before going into the discussion, it has to be mentioned that:

- The analysis presented in this study is the first one for Zarqa City in such details and several additional works and investigations are necessary required as well.
- Despite all negative mentioned aspects and shown pictures in this study, but Zarqa municipality dose a great job, offering good service although the limitation in budget due to the small revenue. The municipality efforts are appreciated and well done in comparison to the available resources.
- Although the top management has enough qualifications, but there is lack of qualifications and experience between workers of lower levels, which means some issues will not have solutions soon. And this requires, first capacity building for all the team of solid waste, and then action adaptations.

5.1 Population and SW Generation

Although some neighborhoods in Zarqa City are saturated, but the city has the potential to grow up, as some neighborhoods may be considered virgin. Furthermore, Zarqa City has a plane to further expansion; this expansion needs future vision to deal with the SW based on integrated plans.

The current population number is around 470,760 and it is expected to reach 597,000 persons by the year of 2030 as shown in Table (4). The population forcasting determined

by taking the average number of all the population future estimation because Zarqa city contains crowded neighbors such as the City Center and Al-Gowereieh where no available space, also it has semi empty neighbors like Al-Ahmad and Shomer and it has neighbors with moderate population density like Qurtoba and Alqamar. So Zarqa city represents all the regime of population growth rates. Annex III contains information about the number of population in each neighborhood, this data will form first step to determine container numbers and size, container distribution in each neighborhood, and container collection frequency.

The average amount of solid waste that is transferred to Al-Gabawi landfill is 291 tons/day. In General, based on the estimation for the total recyclable materials that are recovered at the transfer station and the ones collected by scavengers, the total generated solid waste amount is around 300 tons/day, with a generation rate about 0.64 kg/capita per day. This rate is relatively small in comparison to the generation rate in Amman which is 0.93 kg/capita per day.

By the year 2030, the amount of solid waste is expected to reach 446 tons/day with generation rate about 0.74 kg/capita per day. The annual solid waste generation increment in this research was determined based on sweep net (2010) reported the annual increament in solid waste generation rate for about 3.3%, any way in study done on European cities, it ranged the increment of solid waste generation rate for main EU cities between 1.8 – 4.3% depending on the prosperity of the city, GDP, infant mortality, family size and life expectation. So depending on both studies the solid waste generation rate increments was used as 3.3%. The municipality estimation for the current solid waste amount is

380-400 tons/day. This estimation is based on a brief study done during the holy month of Ramadn last year. So the municipality has over estimated the actual amount of generated SW. Although SW collection services in refugee camps are the responsibility of UNRWA but still the municipality have to collect and transport it, and the bad management of the solid waste in refugee camp affects whole the city. So the municipality should work closely with UNRWA and control the SW management activities in the camp. Furthermore, an urgent need to collect the littered solid waste near the camp and to maintain the awareness and solid waste collection campaigns with participation of all activities in the city.

5.2 Workshops, Scrap Yards and Industrial Area

Although small portion of the generated solid waste in workshops and industrial areas is hazardous, but there is no segregation for it. Both domestic and hazardous waste are mixed together in the domestic solid waste containers. Furthermore, scrap yards require urgent actions for rehabilitation and/or to build new special yards that preserve human and environmental health. The following actions are recommended to control the hazardous wastes in the workshops and industries:

1. Awareness campaign about the expected hazardous waste from each industry and activity, its impact on the general health and environment. Then training course for the hazardous waste dealers about best practices for its handling and disposal.
2. Maintaining an inventory of clearly defined hazardous waste.
3. Instituting auditing procedures for industrial hazardous waste that would lead to compliance with standard regulations.
4. Encouraging waste exchange programs among industries.

5. Instituting hazardous waste prevention and minimization procedures through recycling, recovery and reuse.
6. Taking all the necessary steps to ensure the safe, cost effective treatment and disposal of hazardous wastes.

5.3 Street Sweeping and Solid Waste Collection

lettering is major concern for SW management process, because litter on roadway has to be removed frequently, even if there is no SW littered on street, sweeping still very important to collect the mud and dust that contain serious contaminants such as heavy metals particulate matter that are produced from the vehicles movement on the roads as well as other activities that have to do with the roads (Jang, et al., 2009).

In general, littering problem is dominant problem in Zarqa City especially in the city center, due to lack of containers and bins. City center is crowded and there are no spaces for 1.1 m^3 SW containers, so bins installation will be a good choice for the municipality to reduce SW littering. Moreover, a modern design for the bins can add aesthetic value for city and motivate the people to dispose their waste in it. According to study done in Belfast City (2008), the existence of SW containers in appropriate place will reduce the littering of SW by 34% , reduction of SW littering will save money and time, instead of collecting and sweeping the littered SW the workers can do other tasks.

CEI gives an indication about the littering problem and adequacy of sweeping, a self evaluation system should be adopted by the municipality to sustain good services. Insufficient streets sweeping and solid waste littering are main reasons for low CEI result. Minimizing the littered waste will save money, a pilot project to explore the people

reaction toward bins fixing, and to measure the littering reduction should be done. This will exactly evaluate the benefits of bins fixing.

5.4 Solid Waste Collection and Transportation

The collection and transportation is the main component in SW management process, and if it is done properly it will save time, money and efforts. Bad solid waste containers periodic vehicle damage and lack of site workers are the main challenges for solid waste management in Zarqa city. Furthermore, the lack of data related to the SW management activities is serious issue, and makes the evaluation of SW management hard task. The obstacles are summarized by the following:

- No Records for the SW management process. For example, there are no special records for every vehicle, district. Moreover, there is no weighting for the collection vehicles, where each vehicle when reach the transfer station is considered full loaded, while this assumption is inaccurate.

- The budget is not detailed. For example, in the municipality budget under the solid waste collection costs, there are no specifications related to cost of fuel maintenance, and tools.

- Lack of maintenance for both solid waste containers and vehicles, this increases the pressure on the working vehicles and decrease the efficiency of solid waste collection.

- Poor trained maintenance specialist due to low salaries, so the well qualified specialists prefer to work in the private sector where they pay more.

According to the municipality and Abu Qdais (2007) the current practices of cost recovery for solid waste were not sufficient. The municipality expenditures on solid waste services are greater than the collected fees, this may due to the relatively low level of fees against service, and participation of more than one house with electricity meter, and yet they pay for solid waste collection services only for one house. The gap between the expenditures and the incomes is subsidized from the municipality budget and this causes extra pressure on the budget and reflects on other service and infrastructures offered by the municipality.

One of the suggested solutions to cover the deficit is increasing the solid waste collection and disposal fees. Although this option seems easy to apply but it has social impact and needs to be decided and introduced on a national level supported by a law and may be with clusters for different income level. It has to be assisted by awareness, providing training to solid workers and increasing the waste containers number and improving its status.

It is important to let people know and feel how much they pay for solid waste collection services, because this will have great influence to any future projects or activities aiming to minimize the solid waste generation or altering the current behaviors. There are no specific standards to calculate the solid waste fees especially for the commercial sectors. Anyway, according to the municipality there is a modification for the fee system will be implemented next year. This modification will include standardization of the charge calculations and the form of registration certificate.

Solid waste daily collection is practiced, but there is no specific routing plan assigned for each vehicle. The route determination is left to the vehicle driver and monitored by the

regional supervisors. It happened sometimes that two vehicles were met at the same pick-up point, or some containers were not picked up due to their existence on streets that are common between two regions. Developing proper routing system, where working hours and vehicles travelling distance can be minimized will save money and time for the municipality. To do that, the municipality has to use the available resources, especially the GIS department, where the location of each container should be determined on a map for the city and districts then the best route can be determined. Furthermore, establishing complain system to receive the citizen complain that are related to solid waste to deal with it, and have monthly report to review the systems and the municipality services to develop it in accordance to the available resources.

The SW piles besides containers hinder the work and require longer time to be collected. These piles are due to people insufficient awareness or in many cases the kids are depositing the waste beside the containers because they cannot reach it or unsufficient solid waste container, so the people have to deposit their waste beside the container. It makes solid waste collection process less efficient, raises the costs related to waste collection and increases the collection time and vehicles maintenance and requires more efforts. There is need to adopt actions to organize and minimize the numbers of the accumulated piles, this can be done by enhancing the people awareness, increasing the cooperation between the public and private sectors by adopting program to dispose the waste at certain times, which will minimizes the efforts and costs required to collect it. Finally provide appropriate number of waste container, this can be done by obtaining the number of the tenants in each block (group of homes) and their solid waste generation rate, then the number of required

solid waste containers can be determined. Minimizing the waste piles number will save money between 28,000 JD up to 90,000 JD annually. Moreover, replacement of the damaged container will reduce the cost of solid waste collection between 11,000 JD – 31,000 JD.

5.5 Transfer Station

Transferring the collected solid waste to transfer station then to the final disposal site is good action to reduce the solid waste collection cost. The differences between the amounts of SW sent To Al-Gabawi landfill from Amman, Zarqa and Rusaifeh are listed in Table (16). These differences are accepted due to the difference in population and solid waste generation rate. On the other hand, for Zarqa city the smallest amount of SW that was transferred to Al-Gabawi landfill was in February, because it is the shortest month in the year, while the largest amount of SW was in August because of the Holy Month of Ramadan. In general, solid waste generation rate increases in summer (Al-Khaldi, 2002) because it witness the highest commercial activities and return of the Jordanian from outside of Jordan, this causes significant increase in SW generation amount.

According to municipal tendering registration department, the tenders for SW transportation from the transfer station to Al-Gabawi landfill were 3.75 JD/ton, 3.69 JD/ton and 3.11 JD/ton for the year 2009, 2010 and 2011, respectively. The drop in prices is due to the decrease of the fuel prices and the high competition between the contractors. According to the transfer station workers, the municipality vehicles transported only around 30% of the total transported solid waste to Al-Gabawi landfill. The remaining solid waste was transported by the private contractor vehicles, which means 274,322 JD was paid to the

contractor from the municipality budget to transport the solid waste from the transfer station to Al-Gabawi landfill. This value is not declared in the municipality budget according to the budget department the solid waste budget for 2010 was 300,000 JD; this number is not detailed (as a total summation) and does not include the fuel and maintenances.

The solid waste disposal cost in Al Gabawi landfill is around 3 JD per ton. According to Al-Gabawi manager Zarqa municipality does not pay any fees to dispose its solid waste in the landfill. The SW is transported by municipality and private contractor vehicles; in 2010 the estimated overall cost of SW transporting form the transfer station in Zarqa city to Al Gabawi landfill in Amman was around 389,765 JD, which makes the cost of transportation and disposal around 0.01 JD/ton per km.

The municipality can achieve reduction in solid waste management costs, if it invests and organizes the solid waste transportation process and use the available new vehicles in the landfills. Furthermore, there is shortcut road connect the transfer station and Al-Gabawi landfill but it requires maintenance and extension, and this needs acceptance of the army and the landowners. Using this road will reduce the cost of solid waste transportation.

5.6 SW Characteristics

The sampling procedure is already described in the methodology chapter, the key parameters such as population number, amount of generated solid waste, generation rate organization structure and SW compositions are covered by the previous chapters. However, an additional extensive program are required, such program should cover all the

SW management aspects for enough period of time with participating of the municipality staff to train them and to maintain the process.

The SW sampling and analysis were performed during February and May 2011. During sampling process, the source (district) of the solid waste was considered. According to Al-Khaldi (2002) the variation in solid waste compositions for paper and cardboard plastic, and metals portions between winter and summer were very small and can be ignored. The composition distributions in winter were 2.4%, 14.5% and 1.1% for plastic, paper and cardboard and metal, respectively. While the summer composition distributions were 2.6%, 14.9% and 1.3% for plastic, paper and cardboard and metals, respectively. Although the variations exist for organic, glass and others, but the difference between summer and winter seasons were slightly small. The composition distributions in winter were 77.9%, 1.1% and 4% for organic, glass and others portion, respectively. While in summer it was 78.8%, 1.4% and 1.1% for organic, glass, and others portion, respectively.

Other study conducted by Hanc et al. (2011), it aims to find the composition and other parameters related to the residential organic waste in the four seasons. It concluded that there is no difference in the composition of the organic waste due to season variation. However, even though the organics, glass and other waste portions may be affected by the season's variation but these changes are slightly small and can be ignored.

In this study the obtained results showed that the organic waste is the dominating fraction of SW, where it is around 49%. The high fraction of biodegradable waste requires special considerations regarding the solid waste collection, storage, treatment and disposal system

for example, higher collection frequency are required to avoid odour and waste decomposition. High organic fraction is favorable for composting and methane production. Paper and cardboard, plastic and metals are targeted by the scavengers, they form about 31.5% of the total generated solid waste in the city, which means 91 tons of recyclable materials are generated daily, Table (26) shows the recyclable available amounts and the expected revenues from it according to the current market prices.

Table (26): Expected Revenue from Solid Waste Recyclables.

	Plastic	Paper and Cardboard	Metals
Current Market Price (April,2011) JD/ton	270	70	N.A*
Expected Amount ton	44	38	9
Total Price JD	11,880	2,660	N.A*

*The price of metals vary depending on the type of metal, for example the price of red copper may reach 1,000 JD/ton ,while for the yellow one is around 450 JD/ton.

Since scavenging is a source of income for the scavengers' families, it is recommended to integrate the scavengers within the solid waste management system, by building their capacities to perform their job properly with minimal public health risks.

Anyway, though the people are responsible for the solid waste generation, they have little thought about its impacts. Therefore public participation in the field of solid waste is not common and is not the main interest of decision makers. This means, that awareness and know-how for issues related to solid waste, health and environmental problems is not enough to influence decisions in an effective way. Therefore, population awareness is

prerequisites to implement a solid waste management plan in a satisfactory way. Though there are some steps to raise population awareness, but the actions are inadequate and not systematically done, a comprehensive awareness raising program involving all relevant and interested agencies is still missing. Goals, target group and approach are also not clearly defined yet.

Furthermore, having comprehensive laws and tools to implement such laws are essential to develop the solid waste management process in proper manner. The need for solid waste law or by-law is noticeable. This law should cover all the solid waste management activities from the generation point till the final disposal of the waste; it should determine all the stakeholders and their role.

6 CONCLUSIONS AND RECOMMENDATIONS

This chapter will present the main recommendation, especially for each municipal solid waste issue and will be finalized with main conclusions.

6.1 Conclusions on Zarqa Municipal SW Management

- Zarqa people are responsible for solid waste problems and consequently they are all part of the solution.
- Public and private cooperation is crucial to obtain reliable data, and to increase the benefiting from the recyclable fraction of the solid waste.
- Financial, people behaviors, environmental liabilities are the main concern that affects solid waste services, so any waste management plan should consider them.
- Solid Waste activities are not well recorded.
- There are urgent needs to do some actions to develop the solid waste services and minimize the costs related to solid waste management. For example, using waste bins in the city center, replacement of the damaged waste containers and increase its number, evaluation of the current routing.
- There is need to have comprehensive solid waste law, and tools to enforce it, especially the ones that related to waste separation and minimization.

6.2 Recommendations

1. An additional extensive program of waste sampling and analysis should be carried out to cover all sectors and to get a complete picture and for a better planning.
2. Sampling and analyzing is so important to be an ongoing activity and should therefore be on continues.
3. An immediate action to prepare hiring procedures and specifications based on defined responsibilities and duties as well as qualifications needed (job descriptions and profile of needed staff), where experience in the field of solid waste is condition, is absolutely vital.
4. An assessment of training programs needed for better improvement of the management's ability should be carried out to be implemented as soon as possible.
5. The revenues from solid waste fees have to be improved. This means user charges, disposal fees and other relevant solid waste fees should be reviewed and assessed to finance the operation and maintenance costs at least.
6. The design of public awareness and education approach has to meet the socio-economic status of Zarqa's education.
7. GIS department should be effectively participating in all the activities related to the solid waste management, especially that are related to solid waste collection to minimize the overall costs and solid waste container distribution to optimize the number and locations of distributed containers with the generated amount of SW.
8. Develop records systems to all the solid waste activities. Moreover, complain record is required.

REFERENCES

Abo Hassan, R. (1988), **Routing of solid waste collection vehicles in Irbid**, M.Sc. Thesis Jordan University of Science and Technology, Irbid, Jordan.

Abu Qudais H. (1987), **Solid waste management: An evaluation and possible improvement for the city of Irbid**, M.Sc. Thesis, Jordan University of Science and Technology, Irbid, Jordan.

Abu Qdais H. (2007), Techno-economic assessment of municipal solid waste management in Jordan. **Waste Management**, 27(11), 1666-1672

Abu-Qudais, M. and Abu-Qdais, H. (2000), Energy content of municipal solid waste in Jordan and its potential utilization. **Energy Conversion & Management** (41) 983- 999.

Al-Ansari, N. Al-Hanbali, A. and Dhayaflah, R. (2005), Solid waste Management and Disposal in Mafraq City. **Institute of Earth and Environmental sciences**, Al al-Bayt University , Mafraq, Jordan.

Al-Khaldi, L. (2002), **Feasibility of municipal solid waste recycling in Irbid city** M.Sc.Thesis, Jordan University of Science and Technology, Irbid, Jordan.

American Public Work Association, Committee on Solid Waste (1966), **Refuse Collection Practice**, third edition. Interstate Printers and Publishers, Danville.

Brodrick, C. Lipman, T. Farshchi, M. Lutsey, N. Dwyer, H. Sperling, D. (2002),Evaluation of fuel cell auxiliary units for heavy-duty diesel trucks. **Transportation Research Part D**, 303-315.

Belgiorno, V. De feo, Della Rocca, C. and Napoli, M. (2003), Energy From Gasification of Solid Waste. **Waste Management,** 23, 1-15.

Buah, K. Cunliffe, A. and Williams P. (2007), Characterization of Products from the Pyrolysis of Municipal Solid Waste**, Energy & Resources Research Institute**, The University of Leeds, Leeds, UK.

Cabinet Merlin Consulting Engineers (CMCE), (2002), **Implementation of global solid waste management scheme for the municipality of great Amman**.

Clark, J. Viessman, M. Hammer, M. (1977), **Water Supply and Pollution Control** III edtion, New York, Harper and Row.

EPA.Global warming report (2002), **www.epa.gov/globalwarming**

Hanc, A. Novak, P. Dvorak, M. Habart, J. and Svehla, P. (2011), Composition and Parameters of Houshold Bio-Waste in four Seasons. **Waste Management**.

Hani Abu Qdais (2007), Techno-economic assessment of municipal solid waste management in Jordan. **Waste Management**, 27(11), 1666-1672

Isam Jaradat. (1999), **Municipal Solid Waste Management in Jordan Aqaba Region Case Study.** IHE February 1999.

Jang, Y. Jain, P. Tolaymat, T. Dubey, B. and Townsend, T. (2009), Characterization of Pollutant in Florida Street Sweeping for Management and Reuse. **Journal of Environmental Management**, 91, 320-327.

Kaplan, P. Decarlis, J. Thorneloe, S. (2009), Is It Better To Burn or Bury Waste for Clean Electricity Generation. **Environment Science Technology.(**43)1711-1717.

Li, M. Shao, Z. Ma, H. Zhang, D. Zhang and He, P. (2010), Bio-drying and size sorting of MSW with high water content for improving energy recovery. **Waste Management**, 30 1165–1170.

METAP (2005), In: Proceedings of the Regional Workshop, **Regional Solid Waste Management Project in the Mashreq and Maghreb Countries**, May 7–9 Amman Jordan.

Ministry of Environment and Royal Scientific Society (2009), **Landfills Monitoring Project**.

Menikpura, S. and Basnayake, B. (2009), New applications of 'Hess Law' and comparisons with models for determining calorific values of Municipal Solid Wastes in the Sri Lankan context. **Renewable Energy.** 34, 1587–1594.

Morris, H. (1985), **Basic Statics: A Modern Approach,** III edition, Harcourt School.

Otegbeye, M. Abdel-Malek, L. Hsieh, H. and Meegoda, J. (2009). On achieving the state's household recycling target: A case study of Northern New Jersey-USA.

Pavlas, M. Tou, M. Bébar, L. and Stehlík, P. (2010), Waste to energy - An evaluation of the environmental impact. **Applied Thermal Engineering**. 30, 2326 -2332.

Suttiback, S. and Nitivattananon, V. (2008), Assessment of factors influencing the Performance of solid waste recycling program. **Resource, Conservation and Recycling. (53)** 45-56.

Sweep net (2010), Country Report on Solid Waste Management (2010), activities program The Regional Solid Waste Exchange of Information and Expertise network in Mashreq and Maghreb countries.

Thair, Al abbadi. (2005), **Domestic solid Waste Management in Amman Area: Evaluation of Existing Management**, M.Sc. Thesis Jordan University, Amman-Jordan.

Tchobanoglous, G. Theisen, H. and Vigil, S. (1994)**, Integrated Solid Waste Management Engineering Principles and Management Issues,** I edition, New York, Mac Grow Hill.

Wilson, David. (1977), **Handbook of Solid Waste Management**, Van Nostrand Reinhold Company.

Vesilind, A. Worrell, W. and Reinhart, D. (2002), **Solid Waste Engineering**, Pacific Grove, Brrooks/Cole. USA.

Vesilind, A. and Rimer, A. (1981,) **Unit operation Resource Recovery**, Prentice – Hall Inc. New Jersey.

Zhao, L. Wang, H. Shan, Q. and Liu, H. (2010), Characteristics of gaseous product from municipal solid waste gasification with hot blast furnace slag, **Journal of Natural Gas Chemistry**. 19, 403–408.

Appendix I Domestic Questioner

مشروع رسالة ماجستير بعنوان إدارة النفايات الصلبة في مدينة الزرقاء
تحليل الوضع القائم في المدينة

مقدمة:

السلام عليكم ورحمة الله وبركاته.

أستبيان : المنازل رقم ( )

إسم الحي.......................ألشارع...............................بناية رقم................................

التاريخ: / /2011 الوقت......................

1 - الاسم:(كيف ترغب / ترغبي أن نناديك)؟ (إختياري) كم عدد أولادك؟ ذكور .... إناث .... المستوى التعليمي لرب الأسرة: عمر رب الاسرة ....
2 - هل تعرف \ تعرفي الى أي منطقة من مناطق البلدية يتبع الحي الذي تسكنين فيه؟ نعم لا
3 - كم مضى على إقامتك في هذا المكان؟ 3-0 سنوات 5-3 8-5 10-8 15-10 20-15 25-20 30-25 اكثر من 30 (حدد)
ما اسم الحي الذي تسكنين فيه؟
4 - كم يبلغ دخل الأسرة الشهري؟ اقل من 300 دينار؟ من300إلى 500 دينار أكثر من 500؟
5 - من هو المسؤول عن إخراج النفايات عادة؟ ربة الاسرة رب الاسرة الإبن غير ذلك (حدد) 6 - وكم مرة يتم إخراج النفايات يومياً ؟ مرة مرتين ثلاثة غير ذلك (حدد) 7 - وفي أي وقت يتم إخراجها؟ 8-6 10-8 12-10 14-12 16-14 18-16 20-18 22-20 24-22

8 - هل من الممكن تحديد وقت معين لأخراج النفايات؟
نعم لا

9 - وما هي أقتراحاتكم؟
6-8 ص 8-10ص 10-12 12-14 14-16 16-18 18-20 20-22 22-24

10 -أذا تم تحديد وقت لأخراج النفايات باعتقادك ما هي أمكانية الألتزام من قبل المواطنين؟
الجميع يلتزم الأغلبية ستلتزم قلة ستلتزم لن يلتزم أحد لا أعلم

11 -وهل من الممكن معالجة غير الملتزمين باستخدام المخالفات؟
نعم دائما أحيانا نادراً لا أبداً لا اعلم

12 -أين يتم إلقاء النفايات بعد إخراجها من منزلك بالتحديد؟
في الحاوية بجانب الحاوية على باب المنزل أخرى (حدد)

13 -هل (تقوم / تقومين) بتوجيه الفرد المسؤول عن إخراج النفايات إلى المكان الصحيح لإلقائها؟
نعم باستمرار أحياناً نادراً لا اوجه ابداً

14 -ما هي المسافة بين منزلك واقرب حاوية؟
0-50 م 50-100م 100-150 م 150-200م اكثر من ذلك (حدد)

15 -ما هو نوع الكيس المستخدم في جمع النفايات ؟
أكياس خاصة بالنفايات(السوداء) أكياس التسوق العادية أخرى (حدد)

16 -كم (تقدر / تقدري) كمية النفايات الخارجة من المنزل يوميا في الغالب ؟
كيس كيسين ثلاثة اكياس اكثر من ذلك (حدد)

17 -في أي يوم تكون النفايات اكبر ما يمكن؟
السبت الاحد الاثنين الثلاثاء الاربعاء الجمعة لا أعلم

18 -هل يزيد توليد النفايات في المواسم والأعياد ؟
نعم دائماً أحياناً نادراً لا يزيد لا أعلم

19 -هل يتم استخدام المواد القابلة لإعادة الاستخدام (امثل استخدام العلب الفارغة لحفظ المواد التموينية .....)؟
نعم دائماً أحياناً نادراً لا

20 -هل يتم ببيع المواد التي يمكن بيعها إلى جامعي الخردة؟
نعم دائماً أحياناً نادراً لا

21 -ما هي طبيعة المواد التي يتم بيعها؟ يمكن إختيار أكثر من إجابة
بلاستيك ورق وكرتون أثاث خشبي أجهزة كهربائية معادن زجاج أخرى (حدد)

22 -كيف يتم التخلص من قطع الاثاث الكبيرة مثل: كرسي مكسور، طاولة، كهربائيات تالفة.....؟
رميه بجانب الحاوية رميه بجانب الطريق بيعه التبرع به إصلاحه إستخدامه
في حديقةالمنزل إستخدامه لاغراض أخرى (حدد)

23 -هل يتم نقل الحاوية وتغيير مكانها في الحي الذي تقيم به؟ نعم دائما أحيانا نادراً أبدا 24 -وهل يمكن وضع حاوية أمام منزلكم؟ يمكن لا يمكن
25 -هل يوجد عابثين بحاويات النفايات الملقاة أمام المنزل؟ نعم دائما أحيانا نادراً لا لا يوجد عابثين
26 -في أي وقت تأتي سيارة جمع النفايات؟ 8-6 10-8 12-10 14-12 16-14 18-16 20-18 22-20 24-22
27 -كم عدد عمال النظافة الذين يعملون في الشارع الذي(تسكن/ تسكنين فيه)؟ عامل عاملان ثلاثة عمال اكثر من ذلك(حدد) لا ادري 28 -وهل يساعدونكم عمال النظافة في أعمال أخرى تطلبونها مثل غسيل السجاد و السيارات ...الخ؟ نعم أحياناً نادراً لا لا أدري
29 -هل يقوم العامل المرافق لقلاب جمع النفايات بالتقاط النفايات من أمام منزلك ان وجدت؟ نعم أحياناً نادراً لا لا أدري
30 -كيف تقيم \ تقيمين مستوى النظافة في شارع منزلك ؟ ولماذا؟ ممتاز جيد متوسط ا مقبول سيئ
31 -ماذا تعرف \ تعرفين عن إدارة النفايات في الزرقاء؟
32 -هل من الممكن أن تقومي بفرز النفايات قبل إخراجها من المنزل؟ نعم أحيانا نادرا لا
33 -هل لدك معرفة عن تكلفة جمع النفايات؟ نعم لا
ما هي اقتراحاتكم لتحسين مستوى النظافة وتقليل النفايات الملقاة في الشارع؟
ماذا تظن \ تظنين أن على البلدية أن تفعل من اجل تحسين مستوى النظافة في الشوارع وبشكل عام؟
34 -برأيك هل خدمات جمع النفايات كانت أفضل بالسابق؟ أم إنها أفضل بالوقت الحالي؟ وما هي الأسباب؟

ملاحظات :

Appendix II Commercial Questioner

مشروع رسالة ماجستير بعنوان إدارة النفايات الصلبة في مدينة الزرقاء

تحليل الوضع القائم في المدينة

مقدمة:

السلام عليكم ورحمة الله وبركاته.

إستبيان الفعاليات التجارية والحرفية ..رقم:( )

المنطقة..............الحي..............الشارع...............مبنى رقم..................

التاريخ: / /2011 الوقت..................

35 - إسم صاحب الفعالية (المنشأة) - إختياؤي 36 -النشاط (نوع التجارة،المهنة) 37 -الإسم التجاري
38 -كيف تتخلص من النفايات (الطريقة المستخدمة لجمعها داخل المنشأة)؟ سلة مهملات كرتونة فارغة حاوية سعة 210 لتر اخرى (حدد)
39 -من السؤول عن التخلص منها؟ عامل المحل عامل الوطن صاحب المنشأة أخرى (حدد)
40 -متى تتخلص من النفايات؟ 8-6 10-8 12-10 14-12 16-14 18-16 20-18 22-20 24-22
41 -كم مرة في اليوم تتخلص من النفايات في اليوم ؟ مرة يومياً اقل من مرة يومياً (حدد) مرتين أكثر من ذلك (حدد) 42 -كم تبلغ كمية النفايات المتولدة لديك يومياً؟ 1كغم 2 كغم 3 كغم 5 كغم اكثر من ذلك (حدد)
43 -كم مرة تقوم البلدية بجمع النفايات في اليوم؟ مرة مرتين ثلاثة لا أعلم
44 -لو تم تحديد موعد لجمع النفايات في المستقبل هل تتقيد به؟ ولماذا؟ نعم لا لا اعلم
45 -كيف تقيم مستوى خدمة جمع النفايات التي تقدمها البلدية ؟ ممتاز.......جيد...........متوسط................ضعيف .... غير مقبول ....ولماذا؟

46 -هل لديك معرفة عن كلفة جمع ونقل النفايات؟
نعم لا

47 -ما رأيك بالموعد الأنسب لتحديده لجمع النفايات؟
8-6 10-8 12-10 14-12 16-14 18-16 20-18 22-20 24-22

48 -إذا تم تحديد موعد فهل يمكن أن يتم تصويب غير الملتزمين بواسطة المخالفات؟
نعم لا لا اعلم

49 -هل عدد الحاويات كاف؟
نعم لا لا اعلم

50 - هل موقع الحاويات الحالي مناسب؟
نعم لا لا اعلم

51 -هل لديك استعداد للوصول إلى الحاوية إذا كانت في موقع مناسب؟
نعم لا لا أعلم

52 -ما هي نوعية النفايات المتولدة في المنشأة ؟ يمكن اختيار اكثر من خيار

بقايا طعام ورق وكرتون(مواد تعبئة) بلاستيك معادن زجاج أخرى (حدد)

53 -ما هي كمية النفايات المتولدة باليوم الواحد؟
1 كغم 2 كغم 3 كغم غير ذلك (حدد)

54 -كم عدد عمال النظافة في الشارع الذي يقع فيه محلك؟
واحد اثنين ثلاثة أربعة أكثر (حدد) لا أعلم

55 -ما هي مسافة اقرب حاوية لمحلك؟
50-0 م 100-50م 150-100 م 200-150م اكثر من ذلك (حدد)

56 -هل تعتقد انه ممكن الاستفادة من النفايات التي تطرحها ؟
نعم لا لا أعلم

57 -ماذا تقترح لتحسين مستوى الخدمات المقدمة؟

20-هل ترغب بأن تكون صديقا للبلدية من خلال الأنتساب الى جمعية أصدقاء البلدية؟

نعم لا

ملاحظات :

Appendix III Population Distribution According to Neighbor

Neighbor Name اسم الحي	**Population**	**Area Km^2**	**Population Density**	**Distinct No**
Prince Shaker الامير شاكر	11,225	0.557	20,162	1
Al basateen البساتين	1,492	0.414	3,602	1
Alhusain الحسين	19,234	0.512	37,588	1
Comercial Center الوسط التجاري	15,189	0.698	21,754	1
Garden الحديقه	3,678	0.170	21,648	1
Al nozha النزهه	5,707	0.478	11,948	1
Al dobat - الضباط	3,966	0.173	22,887	2
Al gundi الجندي	5,058	0.493	10,254	2
Jannaa جناعه	17,146	0.743	23,087	2
Al thaura Alkobra الثوره العربيه الكبرى	19,891	1.806	11,013	2
Meccam Al mokarameh مكه المكرمه	195	2.421	81	3
Um Baiadeh ام بياضه	3,444	0.883	3,902	3
Al deowaik الدويك	1,493	1.511	988	3
Prince Hamzeh الامير حمزه	11,311	0.721	15,692	3
White Mount الجبل الابيض	14,595	1.169	12,489	3
Princess Rahmah الاميره رحمه	9,157	0.685	13,375	3
Almadina Almonwarah المدينه المنوره	1,030	2.240	460	4
Nassar نصار	2,057	0.498	4,128	4
Al Ahmad الاحمد	1,159	1.233	940	4
Al bustan البستان	246	1.753	140	4
Shomer شومر	313	4.160	75	4
Al gnenah الجنينه	1,056	0.788	1,340	4
Al zawahreh الزواهره	16,520	2.014	8,203	4
Princess Haya الاميره هيا	4,168	1.987	2,098	4
Al gaber الجبر	1,663	0.861	1,932	4
Qurtoba قرطبه	3,291	0.518	6,357	4
Al qamar القمر	3,139	0.666	4,715	4
Al hashemi الهاشمي	1,438	2.804	513	5
Block Plan ts معامل الطوب	215	1.764	122	5
Southern Hashemiya الهاشميه الجنوبيه	4,608	0.930	4,953	5
Batrawi البتراوي	9,235	5.919	1,560	5
New Zarqa الزرقاء الجديده	23,244	1.932	12,029	5
Al herafeien الحرفيين	29	0.461	63	5
Al naser النصر	12,701	0.468	27,130	6
Maasoum معصوم	22,067	0.877	25,154	6

Neighbor Name اسم الحي	**Population**	**Area Km^2**	**Population Density**	**Distinct No**
Tariq Bin Ziyad طارق بن زياد	5,902	0.483	12,232	7
Al Tatweer Housing اسكان التطوير الحضري	6,164	1.880	3,279	7
Al masaneaa المصانع	2,099	2.393	877	7
Ramzi رمزي	28,155	1.577	17,856	8
Al gowereieh الغويريه	28,413	0.700	40,606	8
Prince Mohammad الامير محمد	14,179	0.428	33,111	8
Housing الاسكان	3,653	0.224	16,281	8
Ibn Sina ابن سينا	6,032	0.362	16,653	8
Barakh برخ	6,931	0.356	19,453	8
Alshiyokh الشيوخ	8,197	0.326	25,113	8
Alfalah الفلاح	7,922	1.919	4,128	9
Prince Hasan الامير حسن	10,423	0.652	15,981	9
King Talal الملك طلال	12,734	0.831	15,318	9
Awajan عوجان	1,463	0.265	5,516	9
Zarqa Camp مخيم الزرقاء	20,000	0.180	111,111	-
Wadi Alish , Al braim Prince Mohammed sport city	57,536	6.034	9,535	-
Total	470,763	64	N.A	N.A

تقييم إدارة النفايات الصلبة في الزرقاء

إعداد

محمد خيري يونس

المشرف

الدكتور خلدون شطناوي

ملخص

هناك اهتمام كبير في حل المشاكل المتعلقة بإدارة النفايات الصلبة في الأردن ، وقد تم القيام بعدد من الدراسات لتقييم عملية إدارة النفايات الصلبة في الأردن. أصبحت إدارة النفايات الصلبة في مدينة الزرقاء تشكل تحديا واضحاً خصوصاً بعد إغلاق مكب الرصيفة في عام 2003. تهدف هذه الدراسة لتقييم إدارة النفايات الصلبة في الزرقاء، تحلل هذه الدراسة عدة عناصر مثل جمع ونقل النفايات الصلبة والمشاكل التي تواجهها البلدية خلال معالجة النفايات الصلبة. علاوة على ذلك تم تحديد معدل توليد النفايات الصلبة، ومكوناتها، والمحتوى الحراري لها وغيرها من مؤشرات أداء الخدمة. كما تم توزيع استبيانات ومن ثم حساب رضا المستخدم كمؤشر على جودة الخدمة المقدمة.

تبلغ كمية النفايات الصلبة المتولدة في الزرقاء حوالي 299 طن/يوم، وبمعدل توليد حوالي 0.69 كيلوغرام في اليوم للفرد الواحد. وتعتبر المخلفات العضوية هي المكون الرئيسي للنفايات الصلبة في مدينة الزرقاء حيث تصل إلى حوالي 48.9% من مجمل النفايات الصلبة المتولدة في المدينة، الأمر الذي يتطلب اعتبارات خاصة لمعالجة النفايات والتخلص منها. أما فيما يتعلق ببقية المكونات فكانت على النحو التالي: 13.3٪، 15.2٪، 3.1٪، 5.8٪ للورق والكرتون, البلاستيك, المعادن, والنسيج على التوالي. كما تم حساب كثافة النفايات الصلبة حيث بلغت ما يقارب 165 كغم/ م^3 . من ناحية أخرى تراوح المحتوى الحراري للنفايات بين 2,121 – 2,905 كيلو كالوري/كغم.

بلغ مؤشر رضا المستخدمين (USI) تجاه الخدمة جمع النفايات الصلبة في المنازل نحو 68٪، بينما بلغ هذا المؤشر حوالي 68.8% للقطاعات التجارية. وعلاوة على ذلك تم استخدام مؤشر تأثير الجماعة (CEI) لتقييم نظافة المدينة، حيث بلغ 53.

تم العثور على بعض أوجه القصور في عناصر إدارة النفايات الصلبة، على سبيل المثال فيما يتعلق بجمع النفايات الصلبة يوجد نقص في القوى العاملة والمركبات، كما أن غياب الحاويات المعلقة (Bins) من مركز المدينة أدى إلى زيادة مشكلة الطرح العشوائي للقمامة. بلغت كلفة تثبيت وإدامة عمل الحاويات المعلقة في مركز المدينة ومحطات الحافلات حوالي 40,463 ديناراً سنوياً. بالإضافة إلى الحالة السيئة للعديد من الحاويات الصندوقية وتلف بعضها ووجود أكوام من النفايات بالقرب من الحاويات الأمر الذي أدى إلى زيادة الزمن اللازم لجمع النفايات، مما تسبب بكلف إضافية لموازنة البلدية تصل إلى 90,000 ديناراً سنوياً. في النهاية إن نقص الموظفين المدربين والوعي لدى الناس وتلف حاويات النفايات الصلبة وغياب التخطيط الشامل كل هذه العوامل مسؤولة عن سوء التعامل مع النفايات الصلبة في الزرقاء.